AUG 5 1927

VOL. 18, NO. 2 AUGUST, 1927

PROCEEDINGS 47TH YEAR

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

PUBLISHED MONTHLY

BY THE

AMERICAN WATER WORKS ASSOCIATION

AT MOUNT ROYAL AND GUILFORD AVENUES, BALTIMORE, MD.

SECRETARY'S OFFICE, 170 BROADWAY, NEW YORK
EDITOR'S OFFICE, 16 WEST SARATOGA STREET, BALTIMORE, MARYLAND

Subscription price, $7.00 per annum

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917;
authorized August 6, 1918

COPYRIGHT 1927, BY THE AMERICAN WATER WORKS ASSOCIATION

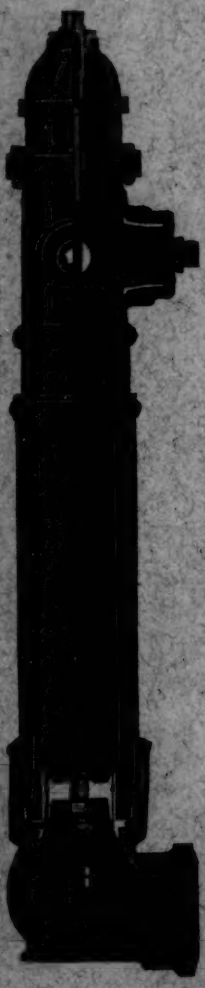
Made in United States of America

Mathews Fire Hydrants

(REG. U. S. PAT. OFF.)

"THE RECOGNIZED STANDARD"
For Domestic or High Pressure Service

FROST PROOF---AUTOMATIC POSITIVE DRAIN
CORRECTLY DESIGNED---RUGGEDLY CONSTRUCTED
FEW PARTS---MINIMUM UPKEEP AND REPAIR



An easily installed

EXTENSION SECTION

and the outer casing make Mathews Hydrants readily adaptable to new grades and conditions.

GATE VALVES

For All Purposes

VALVE BOXES--INDICATOR POSTS
CAST IRON PIPE
(Sand-Cast or "Sand-Spun" Centrifugally Cast)
FITTINGS

R. D. WOOD & CO.

PHILADELPHIA, PA.

SALES OFFICES

Worcester, Mass.	Chicago, Illinois
Petersburg, Va.	Cleveland, Ohio
Lake Worth, Fla.	San Francisco, Cal.
Dallas, Texas	Los Angeles, Cal.

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 18 AUGUST, 1927 No. 2

CONTENTS

A Program for Improving the Water Service in Chicago. By Myron B. Reynolds. 163

Modern Pumping Station Design and Its Probable Future Development. By Arthur L. Mullergren..... 180

Iodization of Public Water Supplies for Prevention of Endemic Goiter. By Robert Olesen 193

Proposed United States Government Specification for Centrifugally-Cast Iron Pipe. By H. A. Stacy and I. J. Fairchild..... 208

Zeolite Water Treatment in a Large Central Heating Plant. By Alfred H. White, J. H. Walker, Everett P. Partridge and Leo F. Collins..... 219

A New Jersey Water Case. By Louis L. Tribus..... 250

Quality of Water and Industrial Development. By W. D. Collins 259

Public Relations. By Daniel T. Pierce 262

Obituary:

John M. Goodell 271

Charles Randolph Wood..... 274

Abstracts..... 276

OFFICERS OF THE AMERICAN WATER WORKS ASSOCIATION

President

JAMES E. GIBSON, Manager and Engineer, Water Department, 14 George St., Charleston, S. C.

Vice-President

WILLIAM W. BRUSH, Chief Engineer, Department of Water Supply, Gas and Electricity, Municipal Bldg., New York, N. Y.

Treasurer

GEORGE C. GENSHEIMER, Secretary, Commissioners of Water Works, Erie, Pa.

Secretary

BEEKMAN C. LITTLE, 305 Cutler Building, Rochester, N. Y.

Editor

ABEL WOLMAN, 16 West Saratoga Street, Baltimore, Md.

Trustees

Term expires 1928	Term expires 1929	Term expires 1930
R. L. DOBBIN	F. E. BECK	LOUIS R. HOWSON
Peterborough, Ont.	Rochester, N. Y.	Chicago, Ill.
GEORGE H. FENKELL	J. O. CRAIG	SETH M. VANLOAN
Detroit, Mich.	Salisbury, N. C.	Philadelphia, Pa.
PATRICK GEAR	THEODORE A. LEISEN	GEORGE W. PRACY
Holyoke, Mass.	Omaha, Nebr.	San Francisco, Cal.

Executive Committee.—JAMES E. GIBSON, WILLIAM W. BRUSH, BEEKMAN C. LITTLE, GEORGE C. GENSHEIMER, ABEL WOLMAN, GEORGE C. ANDREWS, ALLAN W. CUDDEBACK, HARRY F. HUY and the nine Trustees.

Finance Committee.—GEORGE C. ANDREWS, Chairman; CHARLES R. BETTES, E. G. WILHELM.

Publication Committee:—C. A. EMERSON, JR., Chairman; BEEKMAN C. LITTLE, Secretary; ABEL WOLMAN, Editor; JAMES W. ARMSTRONG, A. M. BUSWELL, F. G. CUNNINGHAM, W. W. DEBERARD, WELLINGTON DONALDSON, JAMES E. GIBSON, NICHOLAS S. HILL, JR., FRANK C. JORDAN, JOHN F. LABOON, W. E. MACDONALD, MALCOLM PIRNIE, JAMES J. SALMOND, STEPHEN H. TAYLOR.

Officers of the Divisions

Water Purification Division.—Chairman, WELLINGTON DONALDSON; Vice-Chairman, WILFRED F. LANGLIER; Secretary-Treasurer, HARRY E. JORDAN; Executive Committee, NORMAN J. HOWARD, Immediate Past Chairman, WILLIAM GORE, GEORGE SPALDING and the officers.

Fire Protection Division.—Chairman, NICHOLAS S. HILL, JR.; Vice-Chairman, ALLAN W. CUDDEBACK; Secretary-Treasurer, CLARENCE GOLDSMITH.

Plant Management and Operation Division.—Chairman, W. E. MACDONALD; Vice-Chairman, THOMAS L. AMISS; Secretary-Treasurer, R. B. SIMMS, Trustees, THOMAS HEALY, SAMUEL B. MORRIS.

OFFICERS OF THE AMERICAN WATER WORKS ASSOCIATION (Continued)

Officers of the Sections

California Section.—Chairman, SAMUEL B. MORRIS; Vice-Chairman, J. R. RYLAND; Secretary-Treasurer, PAUL E. MAGERSTADT; Executive Committee, JOHN BURT, P. DIEDERICH, and the officers.

Canadian Section.—Chairman, D. McLEAN HANNA; Vice-Chairman, J. O. MEADOWS; Secretary-Treasurer, A. U. SANDERSON; Immediate Past Chairman, R. H. STARR; Trustees, W. E. MACDONALD, W. C. MILLER, MARCEL PEQUEGNAT; Representative of Canadian Water Works Equipment Association, J. J. SALMOND.

Central States Section.—President, CHESTER F. DRAKE; Vice-President, MENTOR HETZER; Secretary, E. E. BANKSON; Trustees, D. C. GROBBEL, C. P. JAEGER, C. H. WETTER.

Florida Section.—Chairman, ANSON W. SQUIRES; Vice-Chairman, EUGENE MASTERS; Secretary-Treasurer, E. L. FILBY; Directors, term expiring 1927, C. C. BROWN, A. P. MICHAELS; term expiring 1928, L. B. DUANE, W. A. RICHARDS; term expiring 1929, F. W. LANE, F. J. STEWART.

4-States Section.—President, SETH M. VAN LOAN; Vice-Presidents, V. BERNARD SIEMS, L. VAN GILDER; Secretary-Treasurer, CHARLES R. WOOD; Executive Committee, N. E. BARTLETT, W. H. BOARDMAN, H. D. BROWN, J. W. LEDOUX, GEORGE McKAY, and the officers.

Illinois Section.—President, G. C. HABERMEYER; Vice-President, C. M. Roos; Secretary, M. L. ENGER; Treasurer, H. E. KEELER; Trustees, H. M. ELY, W. R. GELSTON, L. R. HOWSON.

Indiana Section.—President, J. W. MOORE; Vice-President, C. E. STEWART; Secretary-Treasurer, C. K. CALVERT; Assistant Secretary-Treasurer, L. S. FINCH; Executive Committee, E. W. AGAR, HARRY GARMAN, J. W. JOPLIN, F. C. JORDAN, WM. LUSCOMBE, J. B. MARVIN, H. S. MORSE, F. P. STRADLING, W. L. YOUNCE.

Iowa Section.—Chairman, J. W. McEVOY; Vice-Chairman, THOMAS J. SKINKER; Secretary-Treasurer, JACK J. HINMAN, JR.; Directors, W. SCOTT JOHNSON, JOHN W. PRAY.

Kentucky-Tennessee Section.—Chairman, W. S. PATTON; Vice-Chairman, F. W. ALBERT; Secretary-Treasurer, F. C. DUGAN; Directors, S. R. Blakeman, W. H. LOVEJOY.

Minnesota Section.—Chairman, G. C. PRUETT; Vice-Chairman, J. W. KELSEY; Secretary, R. M. FINCH; Trustees, OLE FORSBERG, A. D. HORNE, D. A. REED, WILLIAM TODD.

Montana Section.—President, JOHN W. HALL; Vice-President, JOSEPH M. SCHMIT; Secretary-Treasurer, HERBERT B. FOOTE.

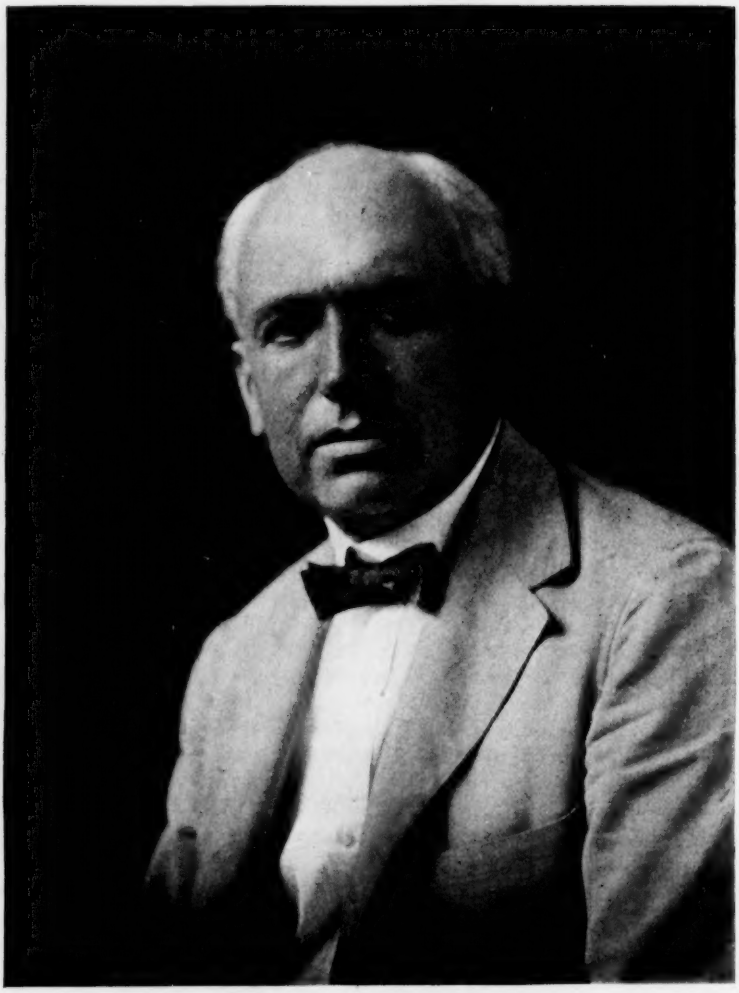
New York Section.—Acting-President, FREDERIC E. BECK; Secretary, E. D. CASE; Board of Governors, FREDERIC E. BECK, E. D. CASE, F. T. KEMBLE, WM. A. McCAFFREY, THADDEUS MERRIMAN.

North Carolina Section.—President, C. M. GRANTHAM; Vice-President, C. E. RHYNE; Secretary-Treasurer, H. G. BAITY; Executive Committee, H. G. BAITY, G. F. CATLETT, J. O. CRAIG, C. M. GRANTHAM, E. G. McCONNELL, H. E. MILLER, C. E. RHYNE, W. E. VEST.

Rocky Mountain Section.—Chairman, PAUL E. STROUSE; Vice-Chairman, L. C. OSBORN; Secretary-Treasurer, DANA E. KEPNER; Directors, term expiring 1928, D. V. BELL, PAUL S. FOX, term expiring 1929, E. C. GWILLIM, C. CICERO OGLE; term expiring 1930, E. A. LAWVER, A. W. STEDMAN.

Wisconsin Section.—Chairman, JOHN KUESTER; Vice-Chairman, ARTHUR J. HALL; Secretary-Treasurer, LEON A. SMITH; Director. H. W. JACKSON.

UNIV. OF MICH.



JAMES E. GIBSON, PRESIDENT, 1927–28

JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings
Discussion of all papers is invited

VOL. 18 AUGUST, 1927 No. 2

A PROGRAM FOR IMPROVING THE WATER SERVICE IN CHICAGO[1]

BY MYRON B. REYNOLDS[2]

In the history of all work of large proportions I presume there is also written the history of the lives of men who have built those works. Three such men have stood out prominently in the history of the water works of Chicago. Honorable DeWitt C. Cregier devoted a long life to the service of the city. Beginning as a steam engineer, he advanced to the office of Commissioner of Public Works and later was elected to the office of Chief Executive of the city. Mr. E. S. Chesbrough was another outstanding figure. A pioneer in water works engineering, he proposed and completed Chicago's first subaqueous water supply tunnel. The last of the three was Mr. John Ericson, late City Engineer, who passed away on April 16th of this year. Arriving from Sweden in his early twenties, he entered the service shortly thereafter. In 1884, when he first took up his work in the field of water works engineering, this city had an area of 36 square miles and a population of 641,000. When he died the boundaries served by the system enclosed an area of 250 square miles and supplied water to a population of 3¼ million people. The plant had increased tenfold during his tenure of office. High tribute is paid to Mr. Ericson as a man and to his integrity as an engineer.

[1] Presented before the Chicago Convention, June 7, 1927.
[2] Acting City Engineer, Chicago, Ill.

It was to have been his honor to deliver a paper this evening on the subject of improving Chicago's water service, and it was with much reserve that I accepted your invitation to substitute for him.

CHICAGO'S WATER WORKS

Chicago's water works system at present is composed of ten pumping stations having a combined capacity of between 1000 and 1100 million gallons per day. There are 6 intake cribs and 70 miles of water supply tunnels. The diameters of these tunnels are from 5 to 16 feet, and the total capacity is between 1400 and 1500 million gallons per day. There are 3400 miles of cast iron distributing mains of sizes varying from 4 to 48 inches in diameter. When the two projects now nearing completion—the Chicago Avenue Tunnel and the William Hale Thompson Pumping Station—are put in service, the capacity of the tunnels will be 2000 m.g.d. and that of the pumping stations 1300 m.g.d.

The routine work of constructing, maintaining and operating the water works system is one of immense magnitude. The preparation of plans and designs, the writing of specifications, the awarding of contracts, and the study of the requirements of the future in our own city and the villages and towns contiguous to its boundary is a business of no small proportions. To provide water for a community which adds to its population a quarter of a million people every four years and to adjust and modify the plant to meet an ever changing character in the occupancy of its areas and sub-divisions are problems of a high technical order. When it is further considered that the promise for the future of Chicago by those whose lives have been devoted to such study is one which has seen no parallel in the history of the world, it may be well to begin thinking and planning, at once, for that future.

The present plant is in excellent condition. During the severely hot days of the summer months it has always been able to deliver water in quantities in excess of its rated capacity. Recent explorations of tunnels constructed sixty years ago show them to be in splendid condition. The same is essentially true of all parts of the system.

Inference may be drawn from the title of this paper that in some respects certain features of the service may be improved upon.

The problem of furnishing water in Chicago, as in all other cities, has always been one of supplying quantity and quality.

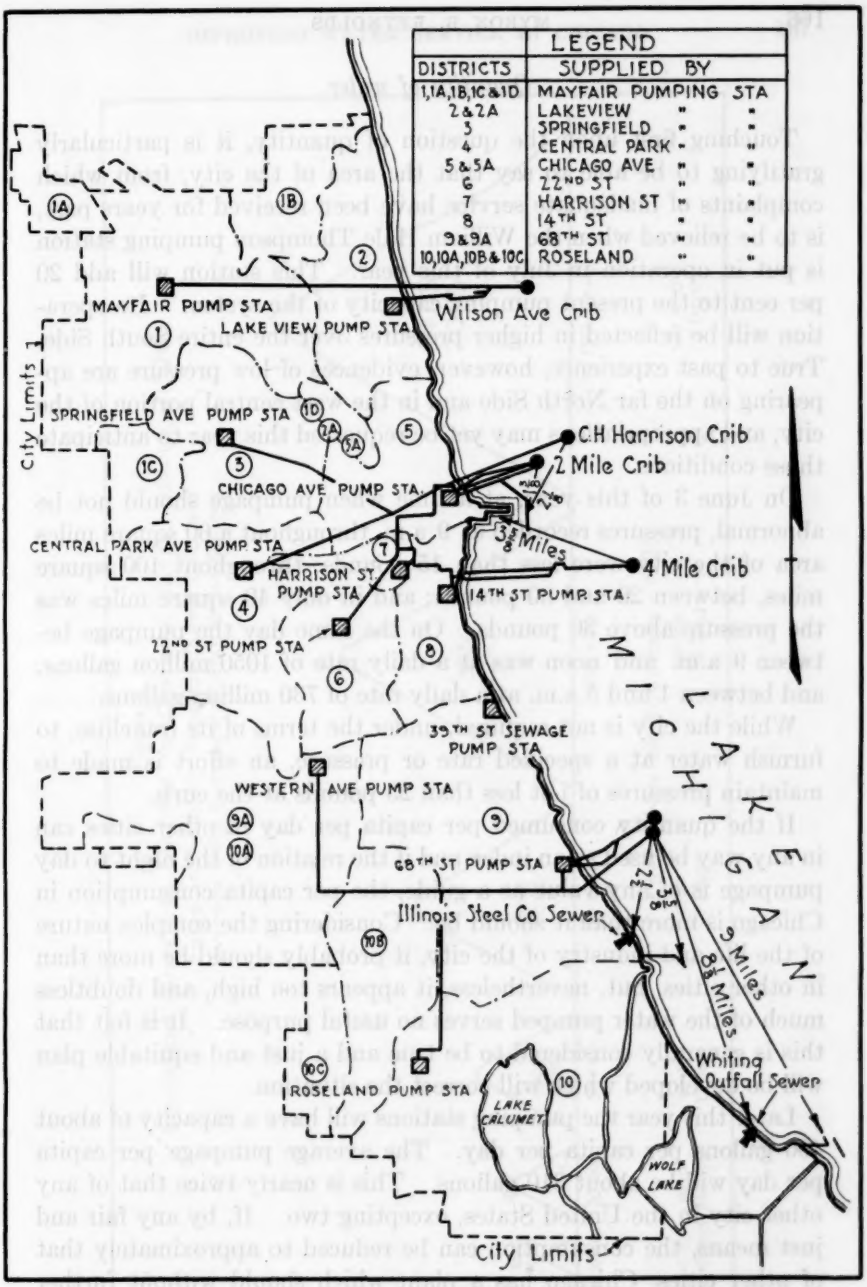


FIG. 1. SHOWING TUNNEL SYSTEM, PUMPING STATION DISTRICTS AND DISTANCES OF CRIBS TO SOURCES OF POLLUTION—SANITARY SURVEY OF LAKE MICHIGAN OFF CHICAGO, MAY, 1927

Quantity of water

Touching first upon the question of quantity, it is particularly gratifying to be able to say that the area of the city, from which complaints of inadequate service have been received for years past, is to be relieved when the William Hale Thompson pumping station is put in operation in July of this year. This station will add 20 per cent to the present pumping capacity of the system. Its operation will be reflected in higher pressures over the entire South Side. True to past experience, however, evidences of low pressure are appearing on the far North Side and in the west central portion of the city, and appropriations may yet be requested this year to anticipate those conditions.

On June 3 of this year, at a time when pumpage should not be abnormal, pressures recorded at 9 a.m. throughout a 60 square miles area of the city were less than 15 pounds; throughout 100 square miles, between 20 and 30 pounds; and in only 40 square miles was the pressure above 30 pounds. On the same day the pumpage between 9 a.m. and noon was at a daily rate of 1050 million gallons, and between 1 and 5 a.m. at a daily rate of 730 million gallons.

While the city is not required, under the terms of its franchise, to furnish water at a specified rate or pressure, an effort is made to maintain pressures of not less than 25 pounds at the curb.

If the quantity consumed per capita per day in other cities can in any way be used as an index and if the relation of the night to day pumpage is of any value as a guide, the per capita consumption in Chicago is more than it should be. Considering the complex nature of the life and industry of the city, it probably should be more than in other cities, but, nevertheless, it appears too high, and doubtless much of the water pumped serves no useful purpose. It is felt that this is generally considered to be true and a just and equitable plan will be developed which will correct the situation.

Later this year the pumping stations will have a capacity of about 400 gallons per capita per day. The average pumpage per capita per day will be about 310 gallons. This is nearly twice that of any other city in the United States, excepting two. If, by any fair and just means, the consumption can be reduced to approximately that of other cities, Chicago has a plant which should without further outlay of capital expense for major projects be sufficient for some ten years to come.

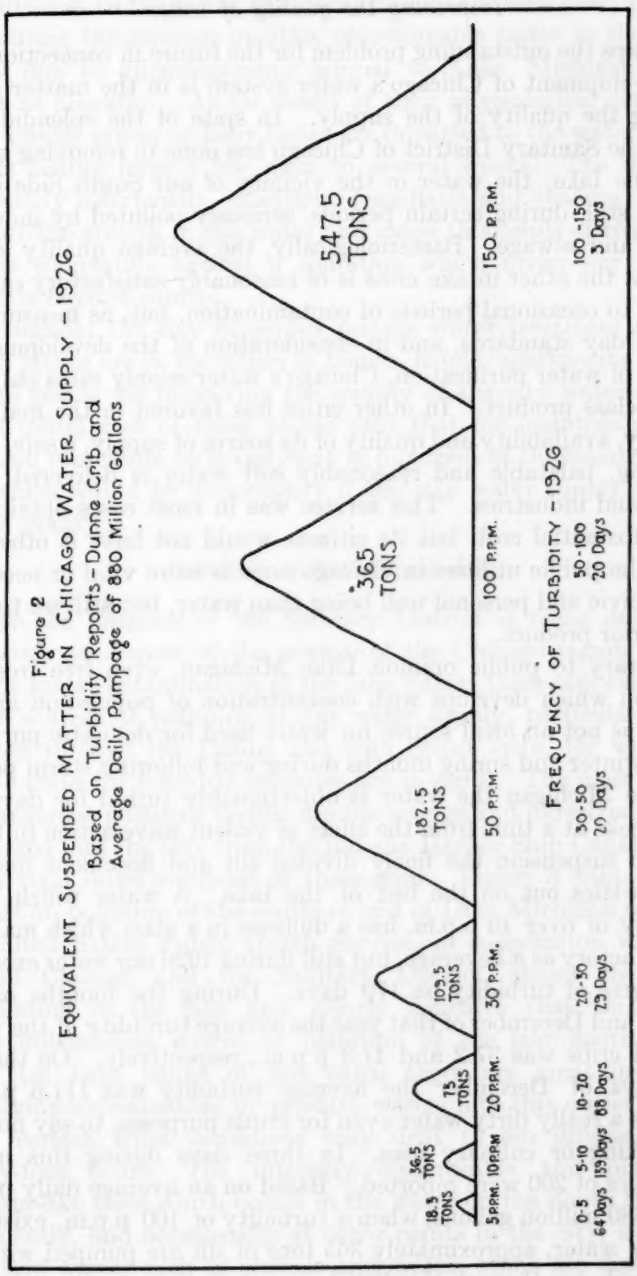


Figure 2
EQUIVALENT SUSPENDED MATTER IN CHICAGO WATER SUPPLY - 1926
Based on Turbidity Reports - Dunne Crib and
Average Daily Pumpage of 880 Million Gallons
547.5 TONS
365 TONS
182.5 TONS
109.5 TONS
75 TONS
36.5 TONS
18.5 TONS
150 P.P.M.
100 P.P.M.
50 P.P.M.
30 P.P.M.
20 P.P.M.
5 P.P.M. 10 P.P.M.
FREQUENCY OF TURBIDITY - 1926
100-150 3 Days
50-100 20 Days
30-50 20 Days
20-30 29 Days
10-20 68 Days
5-10 133 Days
0-5 64 Days

Improving the quality of water

Perhaps the outstanding problem for the future in connection with the development of Chicago's water system is in the matter of improving the quality of the supply. In spite of the splendid work which the Sanitary District of Chicago has done in removing sewage from the lake, the water in the vicinity of our South Side intake cribs is still, during certain periods, seriously polluted by industrial wastes and sewage. Bacteriologically, the average quality of the water at the other intake cribs is of reasonably satisfactory quality, subject to occasional periods of contamination, but, as measured by present day standards, and in consideration of the development of the art of water purification, Chicago's water supply rates only as a second-class product. In other cities less favored in the matter of capacity, availability and quality of its source of supply, a safe, clean, sparkling, palatable and reasonably soft water is delivered to its homes and industries. This service was in most cases obtained at very substantial cost, but its citizens would not have it otherwise. Of all the public utilities in Chicago none is more vital or necessary to our civic and personal well being than water, but still we tolerate an inferior product.

Contrary to public opinion Lake Michigan, even free from the pollution which develops with concentration of population and industry, is not an ideal source for water used for domestic purposes. In the winter and spring months during and following storm periods on Lake Michigan the water is objectionably turbid for days and even weeks at a time from the effect of violent wave action in bringing into suspension the finely divided silt and flocculent material which settles out on the bed of the lake. A water which has a turbidity of over 10 p.p.m. has a dullness in a glass which makes it unsatisfactory as a beverage, but still during 1926 our water exceeded this degree of turbidity on 170 days. During the months of November and December of that year the average turbidity of the water from all cribs was 37.2 and 41.3 p.p.m., respectively. On the first five days of December the average turbidity was 111.6 p.p.m., which is a really dirty water even for crude purposes, to say nothing of drinking or culinary uses. In three days during this month turbidities of 200 were reported. Based on an average daily pumpage of 880 million gallons, when a turbidity of 100 p.p.m. existed in the city water, approximately 365 tons of silt are pumped with the water each day through the distribution system.

In addition to the factor of turbidity there are each year, particularly during the summer months, objectionable tastes in the water supply due to microörganisms normal to Lake Michigan water known as plankton. As the result of their physiological activities, objectionable grassy or fishy tastes are imparted to the water during periods lasting from a few days to several weeks. The diatoms, particularly astērionella, tabellāria, fragellaria and synēdra, have a very prolific growth in our water and cause thousands of citizens to register complaints against a condition which under our present system is beyond control.

Throughout the city numerous private water treatment and filtration plants are in operation in homes, hotels, apartments and industrial plants for improving the quality of the city water supply.

The initial cost of these plants plus that for maintenance and operation represents an investment of hundreds of thousands of dollars, which would be unnecessary if the city water supply were of proper quality.

Pollution of 68th Street crib

While the program of the Sanitary District is being developed adequately to dispose of the sewage of the Chicago region and to prevent gross contamination of the lake waters there still exist very serious sources of pollution of our water supply, particularly that taken in through the Dunne and 68th Street cribs, for which no definite plans for remedial measures are in sight. The most serious and dangerous polluting factors are the sewage and industrial wastes discharged into the lake from the Indiana Harbor Ship Canal, which is only eight miles southeast of these cribs. Figure 3 contained in a report on pollution of the southern end of Lake Michigan made by the United States Public Heath Service, in coöperation with the City of Chicago and the Sanitary District, shows the zones of pollution in the lake and clearly indicates that this outlet is the outstanding source of pollution of the lake south of our cribs. On both banks of this canal there are great industries discharging objectionable by-product wastes into this outlet, which under certain wind conditions may drift to our intakes within twenty-four hours. The intensely disagreeable and obnoxious iodoform-like taste which occurs in the water on the South Side not infrequently, and occasionally at other points in the city, is due to tarry acid wastes such as phenols and cresols which are discharged

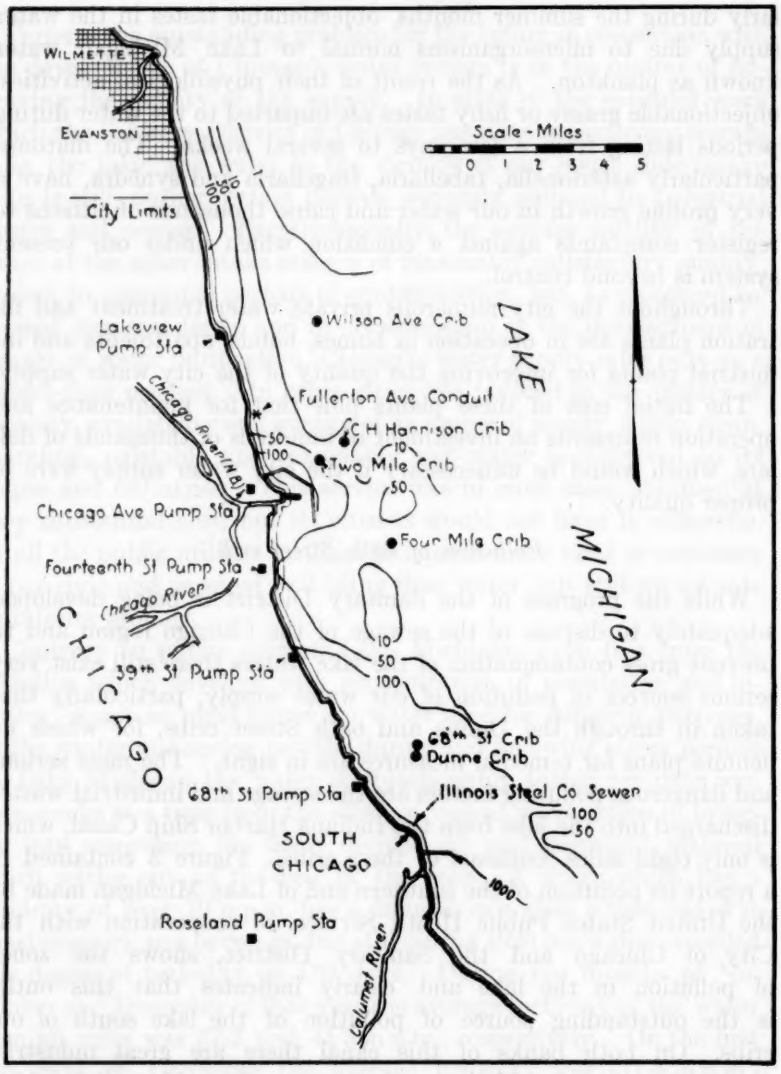


FIG. 3. CONTOUR MAP SHOWING AVERAGE RESULTS B. COLI PER 100 CC. DURING A SANITARY SURVEY OF LAKE MICHIGAN OFF CHICAGO DURING THE YEARS 1924–1925–1926

into the Indiana Harbor Ship Canal. In addition to industrial wastes the sewage of approximately 250,000 people in the Calumet region is discharged into Lake Michigan in the vicinity of Indiana Harbor, grossly contaminating the water and subjecting the 800,000 people who are supplied with water taken through the Dunne and 68th Street cribs to a serious health risk. Oil wastes from the refineries at Whiting also pollute Chicago's drinking water. Even with the construction of filtration plants to purify the water for the South Side this acute taste problem will continue to exist unless measures are taken to keep these wastes out of the lake. The situation is complicated due to the fact that the sources of pollution originate in Indiana and are discharged into an interstate waterway.

Another serious source of pollution of Chicago's water supply is the 80th Street sewer from a large industrial plant. This outlet, from which sewage and plant wastes are discharged, is but 2½ miles from the cribs and has for years been a serious factor from both a health and nuisance standpoint. With the diversion into the Harbor Avenue interceptor in September, 1926, of the sanitary sewage from a plant population of nearly 3000 employes, the public health risk was materially lessened. Studies made since that date indicate that the 80,000,000 gallons per day of waste water still discharged from this plant, and which originally was obtained from the grossly polluted North Slip, continues to contaminate the lake waters to a serious degree.

The Calumet River is the third factor which influences the quality of the water on the South Side. Records collected by the Division of Water Safety Control during the last three years indicate that this river discharges toward the lake something less than 50 per cent of the time. Fortunately, most of the sanitary sewage which formerly discharged into the Calumet River is now intercepted, but the river is still polluted by industrial wastes. Figure 4 shows the concentration of pollution which occurs outside the Calumet harbor entrance when the river discharges into the lake. Were it not for the Government breakwater which flanks the mouth of this river on the north and east, the water about our cribs would be polluted very much more from this source than it is. The plans of the Sanitary District of Chicago for increased diversion at the Sag and dredging of this river to that outlet offer a fair solution of this problem, except for acute storm periods when reversals will take place.

With an investment of about $24,000,000 in cribs, tunnels, pump-

ing stations and distribution mains served by the Dunne and 68th Street intake cribs, and with a system capable of supplying three

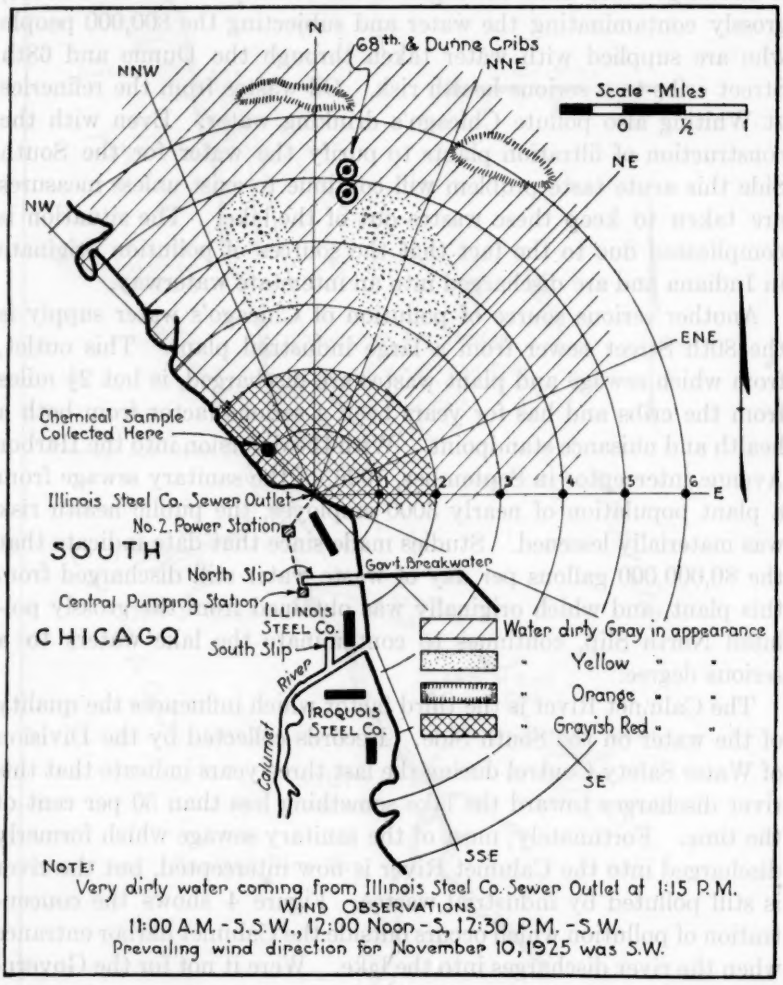


FIG. 4. AREA COVERED BY EFFLUENT FROM ILLINOIS STEEL COMPANY SEWER OUTLET—SANITARY SURVEY OF LAKE MICHIGAN OFF CALUMET RIVER, NOVEMBER 10, 1925

million people, it is imperative that a program for eliminating pollution in the southern end of Lake Michigan be adopted and aggressively carried out. As Chicago is vitally concerned and has the

potential influence necessary to prosecute such a project, it seems logical that it should take the initial step in developing a remedial program. It appears that the problem could be handled in a co-

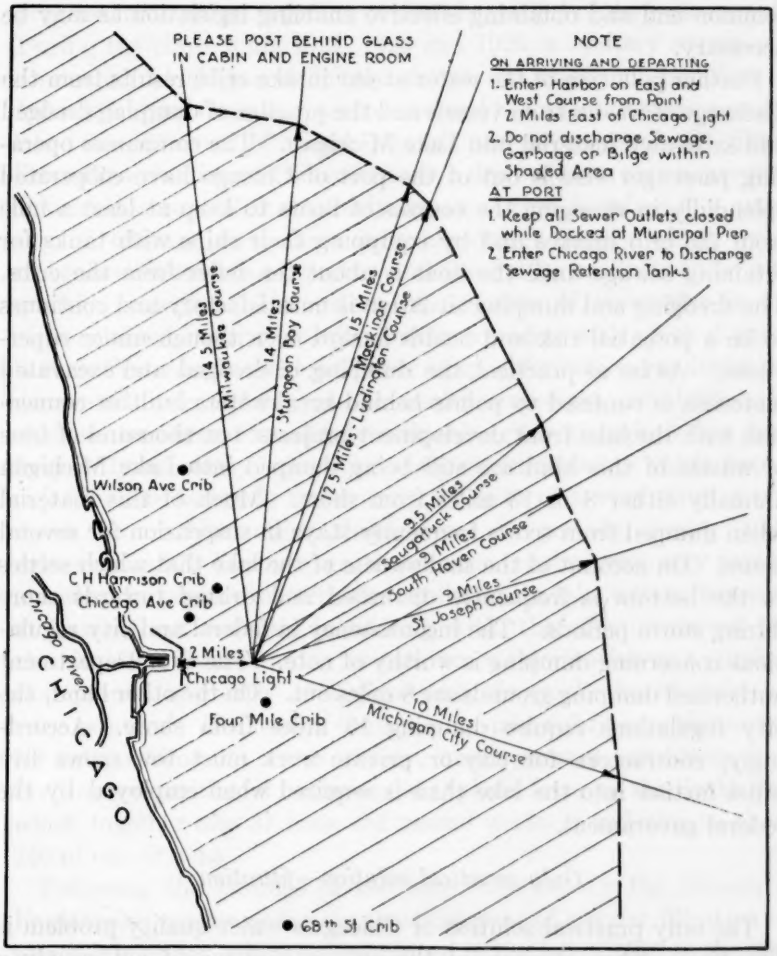

PLEASE POST BEHIND GLASS
IN CABIN AND ENGINE ROOM
NOTE
ON ARRIVING AND DEPARTING
1. Enter Harbor on East and West Course from Point 2 Miles East of Chicago Light
2. Do not discharge Sewage, Garbage or Bilge within Shaded Area
AT PORT
1. Keep all Sewer Outlets closed while Docked at Municipal Pier
2. Enter Chicago River to Discharge Sewage Retention Tanks
14.5 Miles Milwaukee Course
14 Miles Sturgeon Bay Course
15 Miles Mackinac Course
12.5 Miles - Ludington Course
9.5 Miles Saugatuck Course
9 Miles South Haven Course
9 Miles St Joseph Course
10 Miles Michigan City Course
Wilson Ave Crib
C H Harrison Crib
Chicago Ave Crib
2 Miles
Chicago Light
Four Mile Crib
68th St Crib
Chicago River
CHICAGO

FIG. 5. RECOMMENDED COURSES FOR VESSELS ARRIVING AT AND DEPARTING FROM CHICAGO TO AVOID CONTAMINATING THE PUBLIC WATER SUPPLY

operative way between the local state and federal officials concerned, working in harmony with the industries. The United States Public Health Service, the City of Chicago and the Sanitary District have

already coöperated in making careful sanitary surveys which show the extent and effect of pollution of the southern end of the lake. What is now needed is the human machinery to work out a solution for the many local problems, coördinating these efforts to the one common end and obtaining effective enabling legislation as may be necessary.

Further pollution of the water at our intake cribs results from the discharge of wastes from vessels and the practice of dumping dredged and excavated material into Lake Michigan. The companies operating passenger vessels out of the port of Chicago have coöperated splendidly in changing the courses of boats to keep at least a mile from the crib intakes and by equipping their ships with tanks for retaining sewage until the boat is about ten miles from the cribs. The dredging and dumping situation is unsatisfactory and continues to be a potential risk and health hazard even though under supervision. As far as practical, the dumping of dredged and excavated materials is confined to points behind breakwaters built in connection with the lake front development projects, but thousand of tons of wastes of this kind are still being dumped into Lake Michigan annually either 8 or 13 miles from shore. Much of this material when dumped from scows frequently stays in suspension for several hours. On account of the shallowness of the lake that which settles to the bottom is frequently disturbed and drifted towards shore during storm periods. The inconsistency in federal and city regulations concerning dumping is worthy of note. The War Department authorized dumping grounds are 8 miles out. On the other hand, the city regulations require dumping 13 miles from shore. Accordingly, contractors for city or private work must tow scows five miles farther into the lake than is required when employed by the federal government.

Only practical solution—filtration

The only practical solution of Chicago's water quality problem is filtration. The extension of the crib intakes would not supply a satisfactory water. Our investigations show, that objectionable turbidities occur in the water as far as even 8 miles from shore during and following storm periods, and that the presence of plankton in Lake Michigan water at that distance is not materially less than in the vicinity of our present cribs. Thus, it may be seen that, in so far as turbidity and objectionable tastes are concerned, Chicago

would still have an inferior water supply using extended cribs, to say nothing of the high cost of projecting the tunnels and rebuilding the crib intakes.

The City of Chicago has during the last few years made marked progress in its program for improving the quality of the water supply. During the three years 1924, 1925 and 1926, a sanitary survey was conducted which has definitely shown the extent of pollution in Lake Michigan from various sources and the effect of storms on the lake, the influence of winds, rainfall and reversals of the rivers. From these studies and the information derived from experience with chlorination control, it is clearly apparent that filtration is a necessity, if Chicago is to have a public water supply which meets recognized standards of quality and the public health is to be adequately protected. The extent of pollution of the water in the vicinity of our South Side cribs and the rapidity with which it varies is such that continued dependence upon chlorination results in unwarranted risks. As a public health expedient disinfection by chlorine has been exceedingly valuable, even though it has been frequently necessary to use this chemical in amounts which impart objectionable tastes to the water. In spite of a very strict supervision over chlorination there were 47 periods during 1926, representing 273 hours, when the chlorine applied was very rapidly absorbed by organic matter which polluted the lake waters, lessening at least, if not seriously interfering with, the effectiveness of this chemical as a disinfectant. At such times chlorination as a purification process is greatly overloaded and the public health risks are very positive. If Chicago continues to rely solely on chlorination for safeguarding its water supply, under present conditions it is inviting a repetition of outbreaks of typhoid fever on the South Side which together cost 31 lives and caused weeks of suffering to about 340 of our citizens.

Following the findings of the lake front survey the Bureau of Engineering recommended the establishment of a water filtration research laboratory, which was equipped in the fall of 1926 at the 68th Street pumping station. The research work was undertaken with the object of obtaining fundamental data concerning the treatment of Lake Michigan water for filtration. Filter plants of sufficient size to serve the City of Chicago will probably eventually cost between 30 and 50 million dollars, and, although the art of water purification has been highly developed, it was deemed advisable, in view of the

size of the expenditure involved, to conduct preliminary research to see if any modifications might be made in standard filtration methods

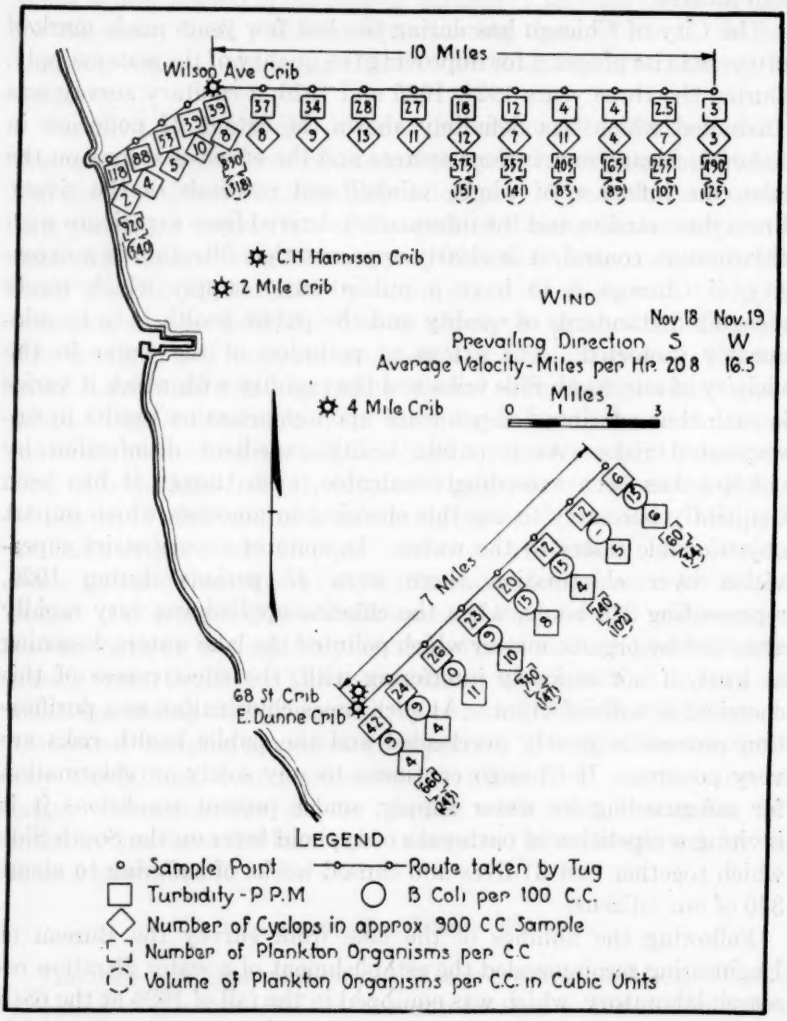


FIG. 6. RESULTS OF SPECIAL SURVEY—LAKE MICHIGAN AFTER STORM NOVEMBER 19, 1926

Tug "Lincoln Park No. 1" used in survey

which would mean the saving of large sums in the plant construction and future operation. This research to date, although only of a

preliminary nature, has indicated that there is great probability that our hopes in this direction may materialize. Therefore, an experi-

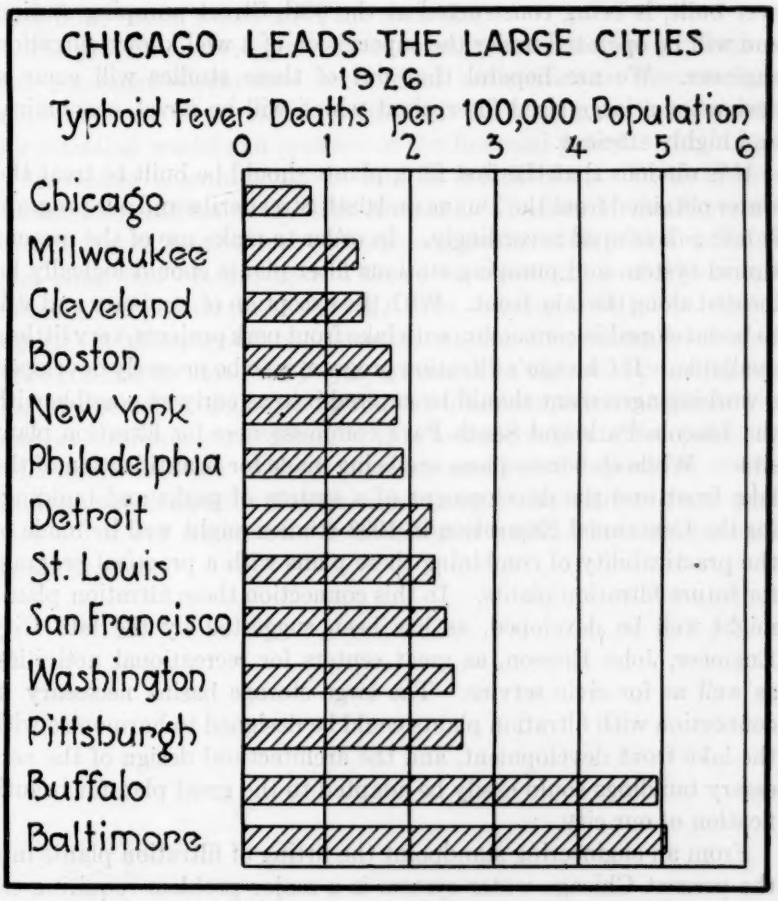


FIG. 7. THE DEATH RATE FROM TYPHOID FEVER IN CITIES OF 500,000 POPULATION AND OVER

Los Angeles is omitted from the figure because no official estimates of population are available. Estimating the population at 1,200,000 the typhoid death rate is 1.08 per 100,000 persons.

mental station has been designed and is now being constructed for making exhaustive studies on the purification of Lake Michigan water.

Experimental water filtration plant

This plant, one of the largest experimental water filtration units ever built, is being constructed at the 68th Street pumping station and will be operated under the supervision of a well known filtration engineer. We are hopeful that out of these studies will come a design for a large sized filter plant which will be novel, economical and highly efficient.

It is obvious that the first filter plants should be built to treat the water obtained from the Dunne and 68th Street cribs and our program is being developed accordingly. In order to make use of the present tunnel system and pumping stations filter plants should logically be located along the lake front. With the exception of land now and still to be developed in connection with lake front park projects, very little is available. If Chicago's filtration program is to be properly developed a working agreement should be entered into as early as possible with the Lincoln Park and South Park commissioners for filtration plant sites. While elaborate plans are being made for beautification of the lake front and the development of a system of parks and buildings for the Centennial Exposition in 1933 studies might well be made of the practicability of combining these plans with a practical program for future filtration plants. In this connection these filtration plants might well be developed, as has been suggested by the late City Engineer, John Ericson, as great centers for recreational activities, as well as for civic service. The large storage basins necessary in connection with filtration plants could be designed to harmonize with the lake front development, and the architectural design of the necessary buildings could easily be adapted to the great plan for beautification of our city.

From an engineering standpoint the fitting of filtration plants into the present Chicago water system is a major problem requiring extensive study. The balancing of the filter and storage capacity against the consumption load for an uninterrupted and economical service will require much engineering ingenuity. The financing of filter plants will require careful consideration and a plan should be developed while other phases of the project are being studied.

In the matter of finances Chicago has until recent years been able to meet all expenditures of the water works through revenues collected from the sale of water. Recently it has been necessary to issue so-called water certificates to meet a portion of the cost of new

construction. At present the outstanding debt is nominal, but it is probable that a revision of the present financial policy will be necessary when the construction of the larger work begins. The sale of long term bonds would meet the situation.

The program covering the question suggests reduction of the present pumpage, coöperation with other authorities to prevent contamination in the southern portion of the lake, provision for sites for filtration works and revision of the financial policy.

In closing a word must be said in behalf of the Water Works Tower, the emblem of the 47th Annual Convention of the American Water Works Association. The thoroughfare upon which it stands is a busy one. It has been widened on the south and widening is nearing completion on the north. The tower stands in the way of the fullest efficiency of the improvement, and its position is insecure. It is possible to move the tower westward on the same property and thereby permit widening of the boulevard for improved traffic service and at the same time preserve this historic structure for posterity. Chicago has too few landmarks which survived the great fire of 1871 and the wrecking activities which go along with progress in any great city. The old water tower is a classic of its kind and deserves this consideration.

MODERN PUMPING STATION DESIGN AND ITS PROBABLE FUTURE DEVELOPMENT[1]

By Arthur L. Mullergren[2]

Within recent years there has been quite a decided change in the design of the large modern pumping stations. This has been brought about by the increasing use of higher steam pressures and temperatures and the rapid development of the steam turbine and centrifugal pump. The present day tendencies of pumping station design are along the lines of the central electric power station. The rapidity with which improvements have been developed in the central power station has been almost phenomenal. In 1914 the average fuel consumption of several of the largest typical central power stations was 1.5 pounds of 14,000 B.t.u. coal per kilowatt hour of station sendout; today there are two of the larger stations producing electric current with 0.9 pound of coal of equivalent heat units per kilowatt hour of net station sendout. This represents a saving in fuel of 37 per cent over a twelve-year period. The various factors contributing to this saving and their relative values are about as follows:

	per cent
Increase in steam pressures and temperatures	12
Use of higher boilers with economizers, air preheaters and improvements in furnaces and combustion equipment	11
Use of electric drive for station auxiliaries	5
Use of the regenerative cycle for feed water heating	4
Improvements in turbines, condensers and auxiliaries	5

In 1914 the central stations referred to operated at a steam pressure of about 200 pounds gauge and a total steam temperature of about 500°F.; today 600 pounds steam pressure with 725°F. total temperatures are in use in a number of the typical stations, and there are two large well known central stations at present operating a portion of their equipment at 1200 pounds steam pressure.

The marked improvements made in central station design are largely responsible for the present day tendencies of large modern

[1] Presented before the Chicago Convention, June 10, 1927.

[2] Consulting Engineer, Kansas City, Mo.

pumping station designs. The water works engineers being more conservative in their views of making any material changes of existing types of equipment and improving economy at a possible sacrifice of reliability have waited until the reliability as well as economy of some of the improved power generating equipment were thoroughly established before taking any steps towards the adoption of such equipment for pumping station practice. The remarkable growth in the use of electric power has made necessary the extensive programs of power station construction, and the power station engineers have been given ample opportunities to develop the improved designs and make tests of the actual performance. After the opportunity was given the water works engineers to determine the reliability, economy and feasibility of adoption of these improved designs for water works practice, they have in the more recent large pumping stations made use of a great many of these improvements in developing the designs that meet the requirements of the particular conditions.

SLOW ADOPTION OF STEAM TURBINE

Water works engineers were at first slow to adopt the steam turbine as a prime mover, largely owing to the fact that the triple expansion pumping engine was a marvel in mechanical and thermal efficiency. As the steam pressure and temperature for this type of equipment could be increased only to a certain point, and then with but slight gain in efficiency, there was little left that could be done in the way of improving station economy. The fuel economy of a triple expansion pumping station engine is very high, and were it not for the very high first cost of this type of installation with its attendant high fixed charges, this type of plant would still be the standard for modern pumping stations. The triple expansion pumping engine costs from $2\frac{1}{2}$ to 3 times as much as the steam turbine driven centrifugal pumping unit, and the building and installation costs are considerably greater. Furthermore, the size of such units is limited to about 50 million gallons daily capacity.

With the increasing demand on the larger water pumping stations, the tendency is towards the installation of pumping units of greater capacity. There are already units installed or contracted for that have capacities in excess of 75 million gallons per day.

INCREASED EFFICIENCY OF PUMPING STATIONS

While the efficiency of the average pumping station has been considerably improved in the last twenty years, it is interesting to compare the efficiency of a large highly efficient pumping station of 1908, the California pumping station of the Cincinnati Water Works, with some of the latest types of pumping stations in use or being installed at the present time. The Cincinnati pumping station operated at a steam pressure of 150 pounds gauge and 125 degrees F. superheat, and had an economizer installed in connection with the boilers. The boilers were of the Stirling type of 2016 square feet of heating surface. The pumping units were 30 million gallon per day capacity, triple expansion crank and fly wheel engines. The superheater was separately fired and the fuel used in firing same was charged against the pumping unit. The tests conducted on this installation in October, 1908, developed the following:

Efficiency of boiler, economizer and superheater	82.2	per cent
Mechanical efficiency of engine	93.3	per cent
Thermal efficiency engine	22.0	per cent
Thermal efficiency plant	16.375	per cent
Duty per thousand pounds steam	194,403,500	foot pounds
Duty per million B. T. U	153,500,000	foot pounds

The above performance was the best that had been obtained at that time and would be considered very good today. The coal used contained 13,254 B.t.u. per pound of dry coal. The overall plant economy was 1.105 pounds of coal per indicated horse power hour.

Probably the best examples of the latest large pumping station designs in this country are the Fairmount Pumping Station, Cleveland; Western Avenue Pumping Station, Chicago; Missouri River Pumping Station, St. Louis. The Fairmount Pumping Station is completed and has been operated a sufficient time to demonstrate the reliability and economy of some of the latest improvements in power plant equipment for pumping station practice. Both the Chicago and St. Louis Stations are under construction and the duties given are the manufacturer's guarantees of expected duties. The Cleveland Pumping Station differs from the others in that the main pumping units were designed to bleed steam for a central heating system, and may be more correctely termed a combined pumping and heating plant; it operates at 300 pounds steam pressure and about 135 degrees superheat. The Chicago Station will operate

at 300 pounds steam pressure and 200° superheat. The St. Louis Station will operate at 300 pounds steam pressure and 245 degrees superheat, or a total steam temperature of about 665°F. This is the highest steam temperature for a pumping station so far designed. Tests made on one of the 75 million gallon per day bleeder units of the Cleveland Station showed a duty when operating without the bleeding feature of 135.5 million foot pounds per million B.t.u.; when operating under the bleeding conditions and allowing for the heat value of the steam bled into the heating system, an overall duty of 198.2 million foot pounds per million B.t.u. was developed. The guaranteed duty of the Chicago Pumping units is 154 million foot pounds per million B.t.u. The guaranteed duty of the St. Louis high duty units is 163.6 million foot pounds per million B.t.u. These three stations embody some of the latest improvements used in central power station design and represent the latest practice in water works pumping station design. No economizers are used in any of the stations, but air preheaters are used in the Cleveland and St. Louis Stations. Stokers are used in all three installations. Steam is bled from the main pumping units for feed water heating.

By comparing the guaranteed duties of the St. Louis steam turbine driven pumping units with the 1908 actual test duties of the California Pumping Station units of the Cincinnati Water Works, it is to be noted that there is a gain in fuel efficiency of only about 7 per cent, which over an eighteen-year period, does not make as good a showing as might have been expected, in view of the gains made in efficiencies in steam generating equipment. However, a comparison of the overall annual charges would show a much greater difference in favor of the present day type of station. If triple expansion pumping engines were used in the St. Louis Station, the initial investment for the complete plant would be approximately $500,000.00 greater than for the steam turbine pumps, and the fixed charges would be approximately $40,000.00 greater per year. Even considering the increased efficiency of the triple expansion pumping units with present day steam practice, namely, 250 pounds pressure, 200°F. superheat, as compared with the steam turbine units with the higher steam conditions, the saving in fuel is only about 8 per cent for the triple expansion unit. The St. Louis officials in tabulating the overall annual charges of the triple expansion unit and the steam turbine unit, found that there was an overall saving under present day conditions of approximately $27,000.00 in favor of the steam

turbine unit. Comparisons made on the Western Avenue Station Chicago equipment under their conditions of operation showed a saving in annual charges of around $67,000.00 in favor of the steam turbine pumping unit.

INCREASING CAPACITIES OF PUMPING STATIONS

With our increasing population and water consumption and the concentration of population in large centers, pumping stations of much greater capacity than those now in use will be required, and engineers must look forward to the future or probable ultimate capacity of the station in selecting the size and type of pumping units. Steam turbines can be built of much greater capacities than present day water works practice require; and therefore there is plenty of margin for the selection of larger equipment for future installations. There are already in use steam turbines of over 100,000 h.p., and the new State Line Generating Station of the Commonwealth Edison Company of Chicago will consist of turbine units of approximately 250,000 h.p. each. The greater the capacity of the turbine, the better the economy, both in fuel and labor charges. Another feature of the steam turbine pumping unit of the latest type is the extreme flatness of the duty curve for variable capacities. On tests made on one of the Cleveland units, there was a change in the duty of less than 7 per cent, with a variation in capacity of two to one. Further improvements will undoubtedly be made along this line, and the future turbine pumping unit will be capable of taking care of a wide variation of output and pressure without appreciably sacrificing efficiency.

Much better economies can be expected in the future in the steam turbine pumping units, if the engineers would specifically set out the requirements of the unit for the particular installation and allow the manufacturers to design it to fit the particular requirements. This calls for special custom machines, but the additional cost will be fully justified. Based on data obtained from manufacturers of steam turbine pumping units table 1 has been compiled showing the expected duties of such equipment in the future, when such units are built for the specific conditions under which they will operate. Such units will probably cost 25 per cent more than the standard commercial machines now being built.

An allowance of about 3 per cent should be made in the above for the auxiliaries. It is fully believed that the above economies will

be realized, as the St. Louis new high service unit guarantees are within 10 per cent of the estimates in the table.

DESIGN OF BOILER PLANT AND AUXILIARIES

With the increasing use of the steam turbine unit, it is essential that the water works engineers consider the design of the boiler plant, auxiliary equipment and selection of plant auxiliaries in a most careful manner in order to obtain the full benefits from the use of high steam pressures and temperatures. The use of the regenerative

TABLE 1

Expected duties for different size units operating under different steam conditions

MILLION GALLONS PER DAY (250-FOOT HEAD)	DUTY: MILLION FOOT POUNDS PER 1000 POUNDS STEAM			
	150 pounds pressure dry sat. steam 28-inch vacuum	200 pounds pressure 200° S.H. 29-inch vacuum	300 pounds pressure 300° S.H. 29-inch vacuum	400 pounds pressure 300° S.H. 29-inch vacuum
10	130.0	173.7	192.2	194.5
15	143.0	190.4	214.0	219.5
20	150.5	199.0	224.0	230.0
25	154.5	204.0	229.8	236.2
30	156.8	207.0	233.0	240.0
40	160.0	211.0	237.0	245.0
50	162.8	214.5	241.5	249.2
60	165.0	217.5	244.9	252.8
70	167.0	220.0	247.4	256.0
80	168.6	222.2	250.0	258.8
90	170.2	224.3	252.2	261.3
100	171.5	226.4	254.4	264.0

cycle of operation with the feed water heated by means of steam bled from the main units has been adopted by nearly all large power stations placed in operation in the last five years. It is felt that two-stage bleeding of the main unit will prove the most economical for water works practice. It is not believed that the re-heat cycle will prove economical in water works pumping station practice. In a great many cases the use of both economizers and air preheaters will be fully justified in water works stations, as they have in central power stations. All auxiliaries should be driven by either electric or water motors, or possibly a combination of the two. Steam driven

auxiliaries are fast disappearing as they are not necessary, since sufficient steam for feed water heating can be bled from the main units at a more economical rate. Electric driven auxiliaries are preferable, in view of their ease in installation and operation and the elimination of a great deal of small piping, which would be necessary with the water motors. It is believed that the most economical arrangement for auxiliary power would be the installation of a direct current generator on the shaft of the main pumping unit, and operate all auxiliaries of the unit by electric motors driven from this generator. The direct current generator would be operated at the pump speed, and therefore does not involve any special design as the present commercial exciters fit this condition. Furthermore, when it is necessary to vary the speed of the main unit for the changing load conditions, the direct-current generator can be regulated automatically to maintain constant voltage and thus not cause any interference with the operation of any of the auxiliaries. Direct-current motors are preferable for auxiliary drive as variable speeds can be obtained without sacrificing efficiency. The electric driven auxiliaries for each unit should be tied solidly electrically with the generator, without the use of fuses, but with thermal relays for protection. These relays can be set high so that there would be no shutdown of any particular auxiliary, unless it was operating near the danger point. The generators and motors as now manufactured have proven that they are as reliable as any other type of motive power and the combined efficiency of the motor and generator will reach about 83 per cent, which is more efficient than the small water motor, or other forms of auxiliary power. The power for the auxiliaries being generated by the most efficient unit in the plant, namely, the main pumping unit, would naturally show a greater overall economy than if separate small prime movers were used. For starting up the plant a small steam turbo-generator could be used, this would not have to be of high efficiency, as it would be seldom called upon. It would be possible to use storage batteries for emergency purposes or for starting up the plant, but it is believed that this extra expense is not justified in the event a house turbine is used.

INCREASED BOILER RATINGS

As long as stokers of comparatively limited grate area were used there was no necessity of going to boiler furnaces of more than moderate sizes. Furthermore, the natural draft chimney placed a limita-

tion on the boiler output. With the introduction of the economizer requiring the necessity of an induced draft fan to remove the gases from the furnaces, and after it was found that they could be removed as fast as the coal could be burned, power plant engineers began experimenting with the possibilities of operating the boilers at much higher ratings. As the boiler ratings were increased, it was found necessary to increase the furnace volume in order that the gases and particles of coal blown up from the fuel bed would be thoroughly burned before they entered the first pass of the boiler. Coincident with the increase in the furnace volume, it was found that the clinker troubles in the fuel bed decreased. It is not known just how far we can go in increasing the output of boilers, but we do know that the limitations have to do with the clinkering in the fuel bed, formation of slag on the lower tubes and also the maintenance of the brick work. Ventilated boiler walls were at first used and the air passing through the walls was used to burn the fuel. It is now recognized that the water cooled boiler wall offers the best solution. A very late type of boiler, known as the steam generator, has the furnace entirely surrounded by boiler tubes connected directly into the boiler circulation and forming a part of the boiler. There is very little brick work and the maintenance of the furnace walls are thus reduced to a minimum. With this design it is possible to burn a greater amount of coal per cubic foot of furnace volume and develop greater capacities from a given boiler, and a smaller amount of excess air is required for the fuel burning, which, of course, improves the overall boiler efficiency. It is possible also to keep the boiler on the line a greater number of hours per year, which in turn reduces the investment required in reserve boiler capacity. The latest development along this line is the Kip's Bay Station of the New York Steam Company. This boiler will generate 325,000 pounds of steam per hour, with a guaranteed efficiency of 88 per cent. The boiler proper has only 10,672 square feet of heating surface, but the total heating surface of the boiler, economizers, air heaters, furnace walls, etc., is 71,600 square feet. This installation uses pulverized coal.

STEAM PRESSURES AND TEMPERATURES SHOULD NOT GO TOO HIGH

It is not felt that the large pumping station should go to the extremely high steam pressures and temperatures which are becoming the practice in central power stations. In the first place, the pumping station cannot operate in the same manner as the power station,

since it is not possible physically to inter-connect pumping stations and operate some as base-load stations, or at high load factors, as with power plants. Furthermore, the pumping station does not have the extremely wide variations in output that the ordinary central power station has. We do believe, however, that later designs of pumping stations will call for 400 pounds steam pressure, 250° superheat and the use of both air preheaters and economizers with the water cooled furnace walls.

USE OF PULVERIZED FUEL

One of the important contributions to the development of power station design and operation is the pulverized fuel method of firing. Pulverized fuel equipment has been in successful use in a number of the larger central power stations for several years and has thoroughly demonstrated its economy as well as its simplicity. Most of the larger installations, however, have been of the so-called central type, that is, the fuel is prepared in a central plant and distributed to the various boilers. Rapid strides have been made recently in the unit type pulverizer, that is, each boiler has its own pulverizing and preparation plant located directly in front of it, so that the entire preparation and burning equipment forms a part of the boiler unit, and it is believed that the future development of pulverized fuel equipment will be along these lines. Test efficiencies as high as 92.9 per cent were obtained in one installation and an overall boiler room efficiency of 90.4 per cent was obtained for a month's operation. Another interesting achievement of pulverized fuel, was the carrying of a load for five days continuously of 13,000 boiler horse power on one of the River Rouge boilers of the Ford Motor Company, having a heating surface of 26,470 square feet, which is equivalent to approximately 500 per cent rating. Unquestionably the future large water works station will be equipped with pulverized fuel equipment, owing to its ability to carry a high sustained load for long periods of time, its adaptability to varying qualities of fuel, its high efficiency, simplicity and small amount of labor required to operate it. One problem in connection with the use of pulverized fuel that will have to be solved, is the design of some form of dust catcher, particularly for the use of stations located in populated sections. Several types of apparatus for this purpose have been developed, but an entirely satisfactory type has not been developed.

IMPROVEMENTS IN STOKER DESIGN

Coincident with the rapid development of pulverized fuel development has been the improvements in stoker design. Both the chain grate and underfeed stokers have been improved considerably and are available in increased sizes and capable of burning the required amount of fuel for each particular installation. Underfeed stokers are available for operation with air temperatures of 400°F. and for burning as high as 35,000 pounds of coal per hour.

In general, the present day design of the modern large pumping station embodies the following:

Operating conditions: 200 to 300 pounds steam pressure, 200 to 250° superheat, or a maximum total temperature of 675°F.

Pumping units: 40 to 75 m.g.d. turbine driven centrifugal pumps, with standard surface condensers.

Boiler room: 500 to 1000 h.p., 250 to 325 pounds gauge pressure boilers, equipped with 200 to 250° convection type superheaters, air preheaters, stokers or pulverized fuel burning equipment, and forced and induced draft fans. Boilers designed to operate at 200 per cent rating.

Auxiliaries: Steam turbine or water wheel operated or combination of both, or combination of water wheel and electric motor driven equipment, with the exception of air removal pumps, which are of the steam jet type.

Coal and ash handling equipment: Overhead bunkers with suitable belt conveyors from coal storage and traveling weighing larries.

Miscellaneous: Automatic combustion control equipment with central control board, necessary gauges mounted thereon, flow meters and control equipment.

Evaporators, deaerators and two-stage bleeding for feed water heating and the use of the regenerative cycle.

FUTURE PLANT DESIGN

The future plant will probably be designed to embody the following features:

Since the tendency in pumping station design is to follow along the practice of large central power stations, it is believed that the future large pumping station will have pumping units of around 150 m.g.d. capacity. Steam turbines have already been developed for capacities far in excess of any horse power that might be required for operating a pump of this size and it will be up to the pump designers to develop pumps that will meet this requirement. Also the reduction gears will necessarily have to be developed for such large capacities. The future unit will have mounted on the main shaft a direct

current generator capable of driving all plant auxiliaries required for the particular unit, as well as the boiler room auxiliaries operating in connection with each main pumping unit. The boilers will be equipped with air preheaters, economizers, both radiant and convection type superheaters, and the furnaces entirely enclosed with water cooled surfaces forming a part of the boiler circulation. The probable steam pressure will be 400 pounds gauge with 255° superheat, making a total steam temperature of 700°F. The unit type pulverized fuel equipment will be installed in connection with each boiler. Evaporators for makeup water and deaerators will be used for feed water purification, and feed water heating will be done by the use of the regenerative cycle, using two-stage bleeding from the main unit. Emergency power supply for plant auxiliaries or for starting up the plant will be provided by a small house steam turbine, and in addition electrical energy will be supplied from the central power station. The overall duty of the pumping unit will be around 250 million foot pounds per thousand pounds of steam. The overall thermal efficiency of the plant will be approximately 20 per cent.

Electric motor drive for smaller stations

All of the above discussion refers to the very large pumping station, or those serving metropolitan districts. For the medium size pumping station or stations having a capacity of less than 30 million gallons per day, it is believed that the future development will be along the lines of electric motor driven pumping equipment, purchasing energy from the large central stations. Large modern central power stations are rapidly covering the country and these plants are being interconnected so as to enable the individual plant to operate at very high load factors and minimize the investment charges for idle or spare equipment. With the increasing tendency along this line and the attendant reduction in the cost of producing power, it will be more economical to purchase power for pumping service than to attempt to produce it. Furthermore, since the water works service offers a very high load factor to central stations and use can be made of very highly efficient synchronous motors for water works pumps, the day is not very far distant when electric power will be available for water works service for 5 mills per kilowatt hour. The investment in electric motor driven pumping equipment, buildings etc., will approximate from 30 to 40 per cent of that of a highly efficient steam turbine driven station. Therefore, the saving in fixed charges will

be another added advantage in the use of electric power. Attention may also be called to the fact that great improvements in efficiencies have been made in motor driven centrifugal pumping units. Tests on a 70 m.g.d. 170 foot head synchronous motor driven pump installed at Detroit, developed an overall efficiency (pump and motor) of 82.7 per cent and a similar test on a 50 m.g.d. 170 foot head developed an overall efficiency of 84.7 per cent. With power costs of 5 mills per killowatt hour and investment charges of 40 per cent of a steam plant, it can be seen that the overall annual charges of such an installation will make a remarkable showing. It is not uncommon to find overall efficiencies in even small motor driven units of 75 per cent.

Owing to the seasonal variations in water consumption, the average pumping station must make provisions in its equipment to take care of this variation. With centrifugal pumps this can be accomplished by the use of so-called base load pumps with other sizes of additional motor driven pumps to suit the particular requirements so that all pumps will operate at their maximum efficiencies when put into service. Owing to the low investment required by motor driven pumps, this arrangement is entirely feasible and economical.

Motor driven pumps as standbys in larger steam stations

It is furthermore entirely possible in the future that even the large steam turbine driven pumping stations may find it economical to have motor driven centrifugal pumps as standby equipment and to fill in the peak demand as occasion warrants, purchasing the power, rather than have a large amount of idle steam equipment that will be used only a portion of the year. The excess fixed charges on the idle steam equipment would probably be greater than the standby charges required by the power company. Furthermore, greater flexibility in operation could be secured by this arrangement. A further advantage of such an arrangement would be the availability, without an extra charge, of standby power for use by the auxiliaries of the main steam pumping units.

Limited field for Diesel engine

It is believed that the Diesel oil engine pumping unit has a very limited field in water works service, except in possibly small stations where electric power is not available at satisfactory rates. While

the Diesel unit has a very high thermal efficiency, its first cost is considerably in excess of the steam turbine driven unit. This is a reciprocating type of unit and may be compared with the triple expansion pumping unit. Both have very high mechanical and thermal efficiencies, but both are very expensive in first cost and require a much larger investment in building and installation costs than a steam unit. I cannot help but feel that it will have a very limited application, the same as the triple expansion pumping engine.

The electric driven pumping station has a decided advantage in the matter of the selection of a site as the power can be brought to the station regardless of its location, thus allowing the engineer to locate the plant at the most feasible site from a water supply standpoint and reducing the cost of tunnels and expensive underground structures, which would be a charge against the plant requiring them. With the duplicate and loop transmission lines supplied by large central stations inter-connected at different points, there can be no reason why an absolutely uninterrupted power supply cannot be given to the pumping stations, I believe it is only a matter of time until power supply interruptions will be unheard of.

Comparative costs of various drives

We have been called upon to make studies of comparative costs of operating a number of medium size pumping stations with purchased electric power, steam and oil engine drive. With power rates as high as $1\frac{1}{8}$ cents per kilowatt hour; coal costs of $4.00 per ton and oil costs of 5 cents per gallon, we have found in a great many cases that the electric drive is the most economical in overall annual charges. Therefore, with the constant reduction in power rates, it is felt that there will be an increasing use of electric driven equipment for the medium size and small pumping station. At the present time the rates in a great many cases might not justify such a conclusion, but the tendency of electric power rates is downward owing to its increasingly efficient production and transmission. At the same time the trend of prices of other fuels is upward. It would seem, therefore, that the pumping station design in the future will be along two lines, namely, the very large steam turbine driven station, designed along the lines heretofore set forth, and the electrically operated station, with motor driven centrifugal pumps using purchased power.

IODIZATION OF PUBLIC WATER SUPPLIES FOR PREVENTION OF ENDEMIC GOITER[1]

By Robert Olesen[2]

GENERAL CONSIDERATIONS

The theory that endemic goiter is due principally, if not solely, to a relative or absolute deficiency of iodine is now widely accepted. The experimental evidence upon which this conception is based is so convincing and the practical applications are so successful that doubts concerning the tenability of the theory are steadily being dispelled.

Following the convincing demonstrations of Marine and his colleagues in preventing goiter among children and lower animals through the administration of small amounts of iodine, public health officials promptly turned their attention to the important matter of applying this new and effective weapon against a disease of long standing. However, in emulating the examples of these pioneer investigators it became apparent that successful prophylaxis is dependent upon the rigid observance of certain well defined and fundamental principles. These requisites for preventing endemic goiter may be stated as follows:

1. Minute dosage of iodine
2. Palatability of the preparation used
3. Efficiency
4. Harmlessness
5. Low cost
6. Wide range and ease of administration

Goiter prophylaxis versus treatment

There is an unfortunate, as well as rather general, misconception of the distinction between goiter prevention and goiter treatment. To many persons the measures advocated for prophylaxis are re-

[1] Reprinted from Public Health Reports, United States Public Health Service, May 20, 1927, vol. 42, no. 20.

[2] Surgeon, United States Public Health Service, Washington, D. C.

garded as being equally efficacious in the treatment of goiter. This erroneous belief is also entertained by many physicians, their goitrous patients being advised to partake of iodized salt or water in order to obtain relief from thyroid disease. Because of the confusion surrounding the subject, it is believed to be advisable to restate the conditions and expectations of goiter prophylaxis.

Prophylactic doses of iodine are intended solely, of course, for the maintenance of the equilibrium of the normal thyroid. The minute doses of iodine suitable for prophylactic purposes probably have little, if any, effect upon existing thyroid enlargements. If goitrous manifestations are reduced or entirly relieved while prophylactic measures are applied, the results may be regarded as incidental rather than usual.

The treatment of existing goiters is a matter entirely removed from the realm of prophylaxis. Treatment requires, first of all, the services of a physician with special skill and experience, particularly in the diagnosis of the different forms of goiter. Furthermore, the medical attendant must possess a keen appreciation of the poisonous potentialities of iodine. As the usefulness of iodine in treating goiter is definitely limited, the possibilities of causing irreparable damage through the use of this element must be thoroughly realized. Needless to say, the breach between goiter prophylaxis and treatment is a wide one. When the essential differences are more generally understood, both preventive and curative measures will be placed upon a more secure basis.

Water and salt as mediums for conveying iodine

Inasmuch as the form in which iodine is conveyed to those in need of the prophylactic is apparently immaterial, numerous preparations, combinations, and methods have been proposed. However, from a practical standpoint it is essential that the iodine be administered in palatable form to all in need of it and with a minimum of administrative supervision. With these objectives in view, investigators began the search for a medium in which iodine could be conveniently distributed.

Water and salt, being the most frequently used articles of food, were naturally chosen early as suitable vehicles for the general distribution of iodine. Iodized table salt is now extensively used in some sections of the United States and Europe, particularly in Switzerland, Austria, and Italy. While the reports as to its effi-

ciency and harmlessness are not in harmonious agreement, nevertheless iodized table salt may be considered a prophylactic of considerable promise, especially after the iodine content has been scientifically adjusted.

When McClendon and Hathaway announced, in 1924, the apparent existence of an inverse ration between the incidence of endemic goiter and the amount of iodine in the drinking water of a given community, interest in goiter prophylaxis was still further increased. In view of the close relationship presumably existing between goiter and the amount of iodine in water, it was but natural that attention should be directed to the possibility of utilizing artificially treated water in preventing simple goiter.

It appears that Dr. G. W. Goler, health officer, in coöperation with Mr. B. C. Little, superintendent of the waterworks bureau of Rochester, N. Y., were the first to propose, and actually put into effect, the iodization of a public water supply for the prevention of simple goiter. Since that time several cities in the United States and England have instituted the same procedure. In the following discussion will be considered the various angles of the subject.

SPECIAL CONSIDERATIONS

Quantity of iodine required for prophylaxis

Much of the objection which has arisen to the use of iodized water in preventing simple goiter is due to the difficulty in establishing and maintaining a suitable iodine content. Iodine must, of course, be present in sufficient quantity to satisfy the thyroid requirements and, at the same time, be incapable of inflicting damage upon the glands of hypersusceptible individuals. McClendon, after a number of years of intensive research, has concluded that the iodization of water supplies in goitrous sections is an acceptable and efficient means of supplying needed iodine. He believes that 0.01 mgm. of iodine daily is sufficient for physiological requirements and, hence, is prophylactic in character. One-tenth of a pound of sodium iodide per million gallons of water would, in McClendon's opinion, be ample for the maintenance of thyroid equilibrium. Water so treated would contain 1 part of sodium iodide in about 100,000,000 parts of water. McClendon believes that the iodide may be supplied continuously or intermittently, the iodide being proportionately increased when the latter method is followed. By following these

suggestions it is theoretically possible, at least, to have a proportion of 10 parts of sodium iodide to 1,000,000,000 parts of water. McClendon regards a region as amply supplied with iodine when the water contains 5 or more parts of iodine per 1,000,000,000 gallons. This line of demarkation between iodine rich and iodine poor water supplies may, in the absence of an established standard, be used as a point of departure in deciding whether the procedure is justified.

Iodization in Rochester, N. Y.

As iodization of drinking water has been carried out more scientifically in Rochester, N. Y., than elsewhere, the methods adopted in that city are of particular interest. Iodization was begun in Rochester in April, 1923, and has been continued twice a year since that time. The experience gained with the early iodization has resulted in considerable improvement and satisfaction with the later methods. At present there are 21 applications of sodium iodide twice a year, each of 16.6 pounds, the first in May and June, the second during October and November. The applications of sodium iodide are now made as follows: During the first week the salt is added daily. Thereafter the additions are made every other day until 21 have been completed. By this means a concentration of iodine ranging between 14 and 28 parts per billion is insured for a period of nearly five weeks. From the actual analyses of the water it is estimated that each person in Rochester ingests 3.1 mgm. of iodine in one year. This amount coincides rather closely with the annual quantity of iodine, 3.65 mgm., recommended by McClendon.

In calculating the quantity of iodine present in water after treatment with an iodide it is necessary to remember that the element iodine is only a portion of the compound ordinarily used. Thus, the percentage of iodine in sodium iodide is approximately 85 per cent. Therefore, in estimating the parts per billion of iodine present in water, the calculations, in the instance of sodium iodide, must be made upon the basis of percentage composition.

Per capita water consumption and iodine dosage

In the absence of accurate knowledge as to the average per capita consumption of water, it is obvious that the amount of iodine ingested from an iodized supply is uncertain. Ordinarily, it is estimated that 2 quarts of liquid are consumed each day by the average person, one-

half of this amount being water, while the remainder is fluid in coffee, tea, and other beverages. Probably an additional quart of liquid per capita is used in cooking, thereby affording another source of iodide.

If each person in need of prophylaxis consumed definite quantities of iodized water and the amount of iodide was sufficient to insure results, this method of supplying the needed element could be relied upon to achieve results. Unfortunately, the consumption of water varies within a wide range, some individuals drinking considerable water while others use relatively small quantities. However, the amount of iodine present in properly treated water is so minute that no harm could possibly result from an excessive consumption of water. On the other hand, it is conceivable that these same minute doses of iodine will prevent simple enlargement of the thyroid gland. At the same time, it must be conceded that the iodine obtained from treated water is likely to be uncertain in quantity.

Objections to the use of iodized water

The objections raised against the use of iodized drinking water as a means of preventing endemic goiter have been numerous. The strongest disapproval has come from the group which discredits all attempts of scientific medicine to minimize the prevalance of disease. Iodization of drinking water is termed by them a "doping" or poisoning process. In view of the minute quantities of iodide used, and the scientific premise on which the procedure is based, the objections of an organized minority may be somewhat discounted. There are, however, certain apparently legitimate objections which deserve consideration. Among these may be mentioned the possibility of inaugurating toxicity in apparently benign goiters, excessive cost, waste, offensive taste, undesirable chemical combinations and the like. Each of these objections may be considered separately.

Cost of iodizing public water supplies

The cost of a public health measure is an item of obvious concern to administrators and tax-payers. It is manifest that goiter prevention should be alloted a fair proportion of public funds commensurate with its relative importance. Heretofore, estimates of the cost of iodizing public water supplies have varied within wide limits. However, the actual expenditures incurred by the city of Rochester for this purpose apparently form a reasonable point of departure for other

calculations. Rochester spends approximately $3000 a year in iodizing its water. As the city has a population of 300,000, the annual per capita cost of the procedure is 1 cent. The sodium iodide used for treating the water costs about $4.30 a pound, delivered in Rochester.

Anaconda, Mont., is another city in which iodization of the public water supply is being practised. The annual expenditure for sodium iodide in this city is $600, or approximately $0.05 per capita, the sodium iodide costing $4.75 per pound f.o.b.

Kimball estimates that it would cost the city of Cleveland $125,000 a year to iodize the drinking water. The health officials of Chicago

TABLE 1

Estimated cost of iodization of public water supplies in 4 cities in the United States

CITY	POPULATION, 1920	AVERAGE PUMPAGE PER DAY	AMOUNT NaI PER DAY	COST NaI PER POUND	COST PER YEAR, 3 WEEKS' DOSAGE TWICE A YEAR	NaI IN THE WATER	COST PER CAPITA YEAR (APPROXIMATE)
		m. g.	*pounds*			*p.p.b.*	*cents*
Rochester, N. Y.	295,750	25	16.6	$4.35	$3,032.82	75	1.0
Sault Ste. Marie, Mich.	12,096	3	2	4.35	365.40	75	3.0
Cleveland, Ohio	796,841	150	100	4.35	12,180* 18,270†	75	1.5 2.3
Cincinnati, Ohio	401,247	56	37	4.35	4,506.60* 6,759.90†	75	1.1 1.6

* Two weeks.

† Three weeks.

estimate that $57,120 a year would be required to increase the iodine content of Lake Michigan water to one-seventy-fifth grain per gallon. With sodium iodide costing $3.75 a pound, delivered, Mellen estimated that the water supply of Minneapolis, Minn., could be iodized at a total annual cost of $6500, or a cent and a half per person. The cost in Duluth, Minn., would be less than $2000 a year.

Bolt and Wolman have prepared an informative summary of costs, shown in table 1, based upon the expenditures in Rochester, N. Y., and Sault Ste. Marie, Mich., and the estimates of Ellms for Cleveland and of Bahlman for Cincinnati.

The costs in this table are based upon the assumption that the quantities of sodium iodide used will be sufficient to secure a content of 75 parts of iodine per billion gallons of water.[3] However, in all probability a greater amount of sodium iodide, and consequently larger expenditures, would be required to secure this concentration. Most of the estimates which have been given indicate that the expense attached to iodization of public water supplies is reasonable, provided, of course, favorable results are forthcoming.

Waste

To many persons the iodization of a public water supply appears to be a wasteful, and consequently an unnecessarily costly, method of conveying iodine to those in need of it. Inasmuch as less than 0.5 per cent of a water supply is used for drinking and cooking purposes, there would seem to be justification for the charge that most of the water is unnecessarily iodized. Obviously, nearly all of any water supply is used for sanitary purposes, laundering, boilers, street flushing, automobile washing, and numerous other purposes unassociated with disease prevention.

However, the same objections may reasonably be raised with regard to other methods of water improvement. The safeguarding of water supplies by filtration and chemical treatment is so well established as to be accepted as a necessity rather than an esthetic refinement or luxury. Thus, raw water supplies are subjected to coagulation, sedimentation, filtration, and disinfection, all expensive processes, in order that the fluid may be made safe for human consumption. Lime, alum, and chlorine are widely used in connection with such water treatment. For softening hard water, lime and soda are frequently employed, while copper sulphate is used as an algicidal

[3] It will be noted that there is a marked difference between the 5 parts of iodine per billion gallons of water regarded as sufficient by McClendon and the 75 parts per billion gallons upon which the cost data presented here are calculated. These estimates were, of course, made by different observers. Obviously, the proper amount of iodine to be conveyed in drinking water for prophylactic purposes is not definitely known. If, as McClendon contends, 5 parts of iodine per billion gallons of water is adequate, the cost of iodizing drinking water would be materially less than the amounts given in the table. It may also be pointed out that the Rochester experiment shows that the amount of iodine recoverable from water after the addition of sodium iodide is much less than the quantity added.

agent. None of the water supplies treated with the chemicals just mentioned are now regarded as drugged, medicated, or doped. Quite on the contrary, the processes are generally conceded to be necessary for the safeguarding of comfort and health, even though only a comparatively small quantity of the water is actually consumed. Moreover, present day opposition to the chemical treatment of polluted or unsuitable raw waters is insignificant, permitting the steady extension of protective measures, with consequent lessening of water-borne diseases.

Reaction between iodine and chlorine

In discussing the iodization of water before the Ohio Conference on Water Purification in 1924, Ellms intimated that an undesirable chemical reaction occurred between the iodine and the chlorine, so commonly used for disinfection. Although his observation lacks confirmation, Ellms contended that chlorine has a tendency to decompose sodium iodide and liberate iodine. While the element would not be lost, its combination with organic matter, or reaction with other normal constituents, might adversely affect its prophylactic value. No objection of similar character has been noted in the literature.

Taste

Much greater quantities of iodine than those ordinarily recommended could be placed in drinking water without imparting a detectable taste. Mellen, for example, states that he has drunk water containing one thousand times the amount of iodide proposed for Minneapolis (10 parts per billion), without being able to detect the taste. It is known, too, that individuals going from a district having water with a low iodine content to another locality with a high iodine content do not complain of an offensive taste. Moreover, there is no record of damage having been inflicted upon the thyroid by reason of removal from a district with low iodine content to one with a high content.

Hyperthroidism

The possibility of stimulating an apparently quiescent thyroid gland to hyperactivity and toxicity through the use of iodine is a contingency particularly to be guarded against while employing prophylactic measures. However, it is difficult to understand how the minute quantities of iodine available in iodized drinking water

could exert such a detrimental effect. It would seem more reasonable to question the ability of the measure to exert any beneficial influence upon the normal thyroid gland. However, as there is convincing evidence that minute doses of iodine, in other combinations, aid in maintaining the thyroid equilibrium, it is likely that iodized water will, under fair conditions, do likewise.

No instances of hyperthyroidism following the use of iodized drinking water appear to have been recorded. The opinion of Dr. C. H. Mayo, concerning the harmlessness of iodized water, is typical of many expressions from physicians who have considered the matter. Dr. Mayo has said, in a communication addressed to the health commissioner of Minneapolis, "As there is no type of goiter which would be injured by the small amount of iodine obtained from the water, I do not believe there would be any risk whatever in such cases."

On the other hand it can not be denied that some physicians are apprehensive lest the "promiscuous distribution of iodine," as they term it, to those not in need of the element, caused a marked increase in hyperthyroidism. Manifestly, there is need for accurate information on this point.

PRACTICAL APPLICATIONS AND RESULTS

Cities using iodized water

So far as can be learned from correspondence with all of the State, county, and city health officers (the last named in cities having populations in excess of 10,000) in the United States there are only two places in which iodization of drinking water is now practiced, Rochester, N. Y., and Anaconda, Mont. Iodization of the Rochester water supply began in April 24, 1923, and will be continued according to an announcement in the Rochester health bulletin of May, 1926, "until, through education or in some other way, we get the people to consume iodized salt."

Iodization of the Anaconda, Mont., water supply began in April, 1925, and was continued in October, 1925, April, 1926, and October, 1926. Children in the Anaconda schools are also receiving 10 mgm. chocolate-iodine tablets once a week for 30 weeks during the school year. Iodization was practiced for a short time in Sault Ste. Marie, Mich. and Virginia, Minn., but was speedily abandoned because of numerous objections from residents.

The health and water works officials of Minneapolis, Minn., have

repeatedly advocated iodization of the public water supply. Moreover, preparations were made to put the procedure into effect. Owing, however, to many objections the project never materialized. In Duluth, Minn., the water and light department of the division of public utilities, has been very active in advocating iodization of the water. According to the investigations made by McClendon, the Duluth water contains the least amount of iodine of any locality in the United States. However, objections have prevented the inauguration of the measure.

In the county of Derbyshire, England, iodization of drinking water was practiced on a limited scale during 1925, the results being reported by the school medical officer. According to J. A. Goodfellow, the water supplies of Ilkeston and Heanor are being treated with sodium iodide. In these last-named places the iodization is continuous, 2 pounds of sodium iodide being added weekly.

Method of adding iodide to water

Owing to the readiness with which sodium and potassium iodide dissolve in water, no difficulty has attended the introduction of these salts in large public supplies. In Rochester the weighed amount of sodium iodide is placed in a bag and allowed to dissolve in the swiftly running water entering Rush Reservoir from Hemlock Lake. That the salt is disseminated throughout the reservoir is attested by the uniform iodine content of water from widely separated city taps. Apparently no special apparatus or means for insuring even distribution of iodine in a water supply are required.

Alleged collateral benefits of iodized water

Quite aside from the beneficent influence presumably exerted upon the normal thyroid gland through the use of iodized water, may be mentioned the advantages of possibly occurring in other directions. In extolling the cause of iodized water, the Water and Light Department of Duluth, Minn., makes the following statement (Bulletin 43, issued in April, 1926):

> Everyone drinks water every day, uses it to water his garden, sprinkle his lawn, lay the dust in the street in front of his house, washes his floors, his clothes, his face and hands, and even bathes in it. If iodized and used on the garden it gives the vegetables and fruits their proper proportion of iodine. Some of it is evaporated into the air where it combats dust carriers of infection. Iodized water for the dairy herds helps to iodize the milk. It is beneficial, even

if breathed into the lungs. However, most of it is washed into the sewers, where it is carried out into the lake, where it prevents goiter in our food fishes. None of the iodine is actually wasted or lost.

Whether, with our present incomplete knowledge of the subject, this enthusiastic view is justified, can only be conjectured.

Results

The chief difficulty in appraising the efficiency of iodized water as a goiter prophylactic arises from lack of clear-cut statistical evidence. In most communities in which goiter is present to an extent sufficient to warrant the institution of prophylactic measures, iodine is available in several forms. In addition to iodized salt, iodine of some other form may be prescribed by the family physician. When the drinking water is also iodized, it is, of course, difficult to decide which of the several measures deserves credit for changes in goiter incidence.

According to the health authorities in Anaconda, Mont., endemic goiter is less prevalent than before prophylaxis was inaugurated. However no accurate figures supporting this impression appear to be available. Owing to the fact that both iodized water and iodine tablets are being used by the school children, it is impossible to ascribe the lessened incidence definitely to either of the two methods.

The health authorities of Rochester, N. Y., claim a reduction in goiter incidence following the iodization of the public water supply. In 1923 there were 3844 children with visible thyroid enlargements; in 1924, there were 1766; and in 1925, 2010. While there has apparently been a decrease in the number of instances of goiter observed, the testimony would be more convincing if percentages based upon the total annual numbers of children of each sex examined were available. Inasmuch as the use of iodized table salt has been recommended in Rochester, it is questionable whether any reduction in goiter incidence may be ascribed solely to the iodization of drinking water.

Derbyshire, England

According to Ash, goiter increased among the boys and girls of four schools in Derbyshire County, England, following iodine prophylaxis. The experiments lasted approximately ten months each, and included the use of iodized water alone, iodized tablets alone, and combinations of the two measures. In each instance Ash recorded a decided in-

crease in the amount of goiter at the second examination. The results of the Derbyshire experiments have been arranged in tabular form in table 2.

An increase in the prevalence of goiter among children following the use of iodine is most unusual and no similar incident has been recorded in the United States. As the numbers of children included in the experiments were small, and no parallel control groups were studied, the validity of the conclusions may be questioned. Iodized water alone was used in only one of the four experiments.

TABLE 2

The effects of one year's use of iodized drinking water and iodized tablets upon the thyroids of the pupils in four schools in the county of Derbyshire, England

SCHOOL	TIME OF EXAMINATION, 1925	IODINE SUPPLIED IN—	AGES	SEX	NUMBER EXAMINED	NUMBER OF GOITERS	PER CENT OF GOITERS
1	February 26	Tablets and water	9–14	Female	306	75	24.5
	December 10				287	192	66.9
2	February 27	Water only	5–10	Female	108	32	29.6
	December 11				118	50	42.3
	February 27		5–7	Male	59	11	18.6
	December 11				50	13	26.0
3	February	Tablets only during first half year	7–14	Female	271	127	46.8
	January, 1926	Water only during second half year			283	146	51.5
4	March	Tablets only during second half of year.	10–18	Female	151	62	41.3
	December				131	85	64.8

The results of the experiments in which both iodized water and iodized tablets, or iodized sweets, as Ash calls them, were used, are an indictment of iodine prophylaxis rather than the methods employed. It is felt that the time during which the experiments were carried on was too short to permit of an accurate appraisal of either of the methods employed. It would be interesting to learn something of the status of the several groups one year after the complete withdrawal of iodine.

Opinions of health officers concerning iodized water

The proposal that endemic goiter be prevented through the medium of drinking water has created widespread interest. Health officers, especially, have manifested marked interest in the possibilities of the measure. In an effort to learn the attitude of county and city health officers toward iodized water, a questionnaire was addressed to 1040 workers of this type in the United States. The replies, received from 56.3 per cent of this group indicate an uncertainty concerning both the justifiability and efficiency of treating drinking water with iodine. The answers received from 566 health officers may be tabulated as follows:

Favorable to use of iodized water	159, or 28 per cent
Undecided	105, or 18.5 per cent
No opinion	202, or 35.7 per cent
Opposed to measure	100, or 17.7 per cent
Total	566

CONCLUSIONS

The iodization of public water supplies, in its present state of development, can not be recommended for widespread adoption. However, the measure appears to be theoretically sound and promising as a means of reducing goiter incidence when correctly used. The chief points in its favor are its comparatively low per capita cost, its apparent harmlessness even to existing goiters, and its wide range of applicability.

So far, there is considerable doubt as to the ability of iodized water to reduce the incidence of endemic goiter. This important point should be clearly established before further commendation of the measure can be forthcoming. However, the lack of convincing evidence of the efficiency of iodized water appears to be the result of poorly controlled experimental applications, rather than of any inherent defect of the procedure itself.

While the measure can not be recommended for wider use until stronger evidence concerning its value is forthcoming, nevertheless, iodized water should not be condemned as worthless. Rather there is need for more precise experimental work, with careful and repeated thyroid examinations, both of children as well as adults. Comprehensive control experiments in nearby communities, among groups which are not consuming iodized water, are also essential. In con-

junction with these precautions, it is also desirable that epidemiological observations be made for the purpose of learning whether other iodine preparations are being used. The results of such scientifically performed experiments would readily disclose the worth or worthlessness of iodized drinking water as a means of preventing simple goiter.

REFERENCES

ASH, W. M.: Goiter. Jour. State Med., London, **34**, 627 (November, 1926.)

BAHLMAN, C.: The Application of Iodine to Public Water Supplies. Report of Ohio Conference on Water Purification, November 21–24, 1923.

BILLARD, G.: Natural Iodized Water. Presse méd., **26**, 118 (October 7, 1918).

BOLT, R. A., AND WOLMAN, A.: The Treatment of Water with Iodide for Prevention of Simple Goiter. Manual Amer. Water Works Practice, p. 268. The Williams & Wilkins Co., 1925.

Chicago menaced by goiter. Chicago Department of Health Weekly Bulletin, **17**, 34, 137 (August 25, 1923).

CLARK, H. W.: Iodine and Water Supplies. Water Works, **65**, 1, 44 (January 13, 1926).

Duluth (Minn.) Water and Light Department, Bulletins 42, 43, 44, 45, and 46.

ELDRIDGE, E. F.: Iodine Content of Michigan Water Supplies. Jour. Amer. Pub. Health Assoc., **14**, 9, 750 (September, 1924).

ELLMS, J. W.: The Use of Iodine in Public Water Supplies. Report of the Ohio Conference on Water Purification, November 21–24, 1923.

English comments on addition of iodine to drinking water to prevent thyroidism: From the chemical laboratories of the Royal Institute of Public Health, Jour. State Med., **34**, 1, 59, January, 1926, Abst. Jour. Amer. Water Works Assoc., **15**, 4, 409 (April, 1926).

GOODFELLOW, J. A.: Goiter and Drinking Water. Mun. Eng. and San. Rec., **75**, 526 (1925).

HIGHLAND, S. G.: Iodine Treatment of Water. Canadian Engineering, **47**, 220 (1924). (Chem. Abst., **18**, 22, 3665 (November 20, 1924).)

HOUSTON, SIR A.: The Medication of Water Supplies. The Medical Officer. January 24, 1925, p. 41.

JOHNSON, H. M.: Iodine, Goiter, and Public Water Supply. Jour. Amer. Water Works Assoc., **16**, 2, 205 (August, 1926).

LITTLE, B. C.: Iodine Treatment of Water for Prevention of Goiter. Jour. Amer. Water Works Assoc., **10**, 4, 556 (July, 1923).

LITTLE, B. C.: Sodium Iodide Treatment of Rochester's Water Supply. Jour. Amer. Water Works Assoc., **12**, 1, 68 (September, 1924).

MCCLENDON, J. F., AND HATHAWAY, J. C.: Inverse Relation Between Iodine in Food and Water and Goiter, Simple and Exophthalmic. Jour. Amer. Med. Assoc., **88**, 21, 1668 (May 24, 1924).

MCCLENDON, J. F., AND HATHAWAY. J. C.: The Determination of Iodine in Food, Water, and Drink. Jour. Biolog. Chem., **69**, 2, 289 (June, 1924).

MELLEN, A. F.: Use of Iodides in Water Supplies to Prevent Simple Goiter. Eng. News Record, **95**, 9, 352 (August 27, 1925).

MELLEN, A. F.: The Present Status of Iodine in the Minneapolis Water Supply. Jour. Amer. Water Works Assoc., **16**, 6, 715 (December, 1926).

Minneapolis, Iodine in Water for Goiter Prevention. Editorial, Journal-Lancet, **44**, 14, 381 (July 15, 1924).

Montana Fights Goiter with Sodium Iodide. Eng. News Record, **97**, 10, 378 (September 2, 1926).

RICH, E. D.: Iodine Treatment in Michigan. Jour. Amer. Water Works Assoc., **14**, 4, 325 (October, 1925).

ROBERTSON, H. E.: Certain Obscure Relations of Drinking Water to Disease, Jour. Amer. Water Works Assoc., **9**, 1, 46 (January, 1922).

Rochester (N. Y.), Iodine and Goiter. Bulletin of the Health Bureau, Rochester, N. Y., April, 1924, p. 2.

SCOTT, L. C.: Résumé of the Goiter Situation. Quarterly Bull. of Louisiana State Board of Health, **16**, 4, 227 (December, 1925).

SHERMAN, H. A.: Iodine Treatment of Sault Ste. Marie (Mich.) Water. City Manager Magazine, December, 1923.

WILLIS, A. B., AND GOLER, G. W.: Iodide in Rochester's Water Supply. Bulletin of the Health Bureau, Rochester, N Y., May, 1926, p. 3.

PROPOSED UNITED STATES GOVERNMENT SPECIFICATION FOR CENTRIFUGALLY-CAST IRON PIPE[1]

By H. A. Stacy[2] and I. J. Fairchild[3]

A survey of recent Federal installations having indicated the growing importance and acceptability of cast iron pipe made by centrifugal processes, the Pipe Committee of the Federal Specifications Board decided to attempt the preparation of specifications for this material. The specification, when adopted by the Federal Specications Board, will become the official purchase standard for all activities of the United States Government.

Other reasons leading to the decision were (1) the greater strength of centrifugal pipe compared with vertical sand cast pipe, (2) greater homogeneity, (3) smoother interior, (4) lighter weight, and (5) lower cost when laid. Furthermore, conditions in the industry indicate that centrifugally cast pipe may possibly supplant other pipe in the small sizes due to a faster rate of production with fewer men, (one DeLavaud machine with 5 men will produce 30 to 40 lengths of 6-inch pipe per hour) and better working conditions which reduce the uncertainty of the skilled labor problem.

In the United States, mass production of centrifugal pipe is confined to two general methods, (1) the DeLavaud process (used by the United States CastIron Pipe and Foundry Company at their Burlington, N. J., and Birmingham, Ala., plants, and by the National Cast Iron Pipe Company, which employs a revolving, water-cooled, metal mold), and (2) the "Mono-cast" or "Sand Spun" method (used by the American Cast Iron Pipe and Foundry Company and R. D. Wood and Company), in which the revolving metal flask is lined with skin-dried, green sand. No cores are required in either process except for the bells.

[1] Published by permission of the Chief Coördinator, Bureau of the Budget, Washington, D. C.

[2] Associate Engineer, Bureau of Yards and Docks, Navy Department, Washington, D. C.

[3] Chairman, Technical Committee on Pipe, Fittings, Valves, etc., Federal Specifications Board, Bureau of Standards, Department of Commerce, Washington, D. C.

The preliminary study revealed a number of obstacles in the way of purchasing this pipe on a competitive basis. First, the pressure classes or ratings are different, the DeLavaud pipe (4- to 12-inch size) being made for working pressures of 50, 150 and 250 pounds per square inch while the Mono-cast or Sand Spun pipe is made for 100, 150, and 250 pounds per square inch; second, thicknesses for the same working pressures seem to bear no relation to each other; third, the thicknesses now used in either process bear no logical relation to any of the accepted formulas for cast iron pipe; fourth, the lengths are inconsistent, 12 feet being used in the DeLavaud process while 16 feet lengths are regular for Mono-cast and 16 feet 4.85 inches (5m) lengths for Sand Spun; fifth, the former omits the bead on spigot end for all sizes and classes in contrast to the latter which retains the bead: sixth, there is a discrepancy in outside diameters for sizes above 12 inches; and seventh, dimensions of the bells are different.

Such differences would seem irreconcilable; however, it is believed each obstacle has been surmounted in a manner acceptable to both producer and consumer. The practical limitations of tolerance in manufacture, considerations involving predominating values of pressure and standard pressure ratings for small iron pipe fittings, led to the empirical adoption of 150 and 250 pounds per square inch as preferable working pressure ratings.

To provide a basis for selection of thickness dimensions, the Brackett, Fanning and other formulas were studied, and many papers citing the experience of water departments were digested. In general, experience with regular sand cast pipe indicates that the present thicknesses are more than adequate for the smaller sizes and are not entirely dependable for the larger sizes. The Brackett formula which seems to be most favored at present and which provides for a gradual reduction in allowance for water hammer with increase in diameter appeared to be most nearly logical, except for the second term. Therefore a new formula was worked out, which for convenience we will call the Fairchild formula, as follows:

$$t = \frac{fd\ (P + P^1)}{2S} + \frac{0.30}{d^{0.3}}$$

in which t = thickness in inches
f = factor of safety (4 for centrifugal pipe)
d = nominal interior diameter, inches
S = ultimate stress, lbs. per sq. in.

P = working pressure, lbs. per sq. in.
P^1 = pressure due to water hammer as follows:

DIAMETER	P^1
inches	
4–10	120
12	110

Ultimate stresses in tension test specimens of DeLavaud pipe have been reported well above 40,000 pounds per square inch. However, stresses computed from actual bursting pressures indicate that the bursting strength may fall as low as 15,000 pounds per square inch, due, no doubt, to the fact that hydrostatic tests search out the thinnest spots or the weakest portions of the pipe. We have therefore selected 20,000 pounds per square inch as a safe ultimate stress and have used a factor of safety of 4 instead of the usual 5 as a concession to the homogeneity and general structure of the metal. The formula thus reduces to $t = \frac{d(P + P^1)}{10{,}000} + \frac{0.3}{d^{0.5}}$.

The second term of the formula provides an additive correction value of from 0.2 inch for 4-inch pipe to 0.08 inch for 72-inch pipe to allow for eccentricity, handling, corrosion, etc. Since centrifugally cast pipe is more uniform in thickness and is not particularly subject to eccentricity, it follows that the corrective term should be less than for other pipe. The form of the second term was chosen to provide a logical correction for all sizes including those beyond the present range of production. The second term of the Fanning formula passes through zero when $d = 100$ inches; in the Fairchild formula the second term changes more and more slowly as the diameter is increased until at 72 inches diameter it becomes nearly constant. This formula therefore provides a relatively greater correction value for the larger sizes of pipe without unduly penalizing the smaller sizes. Though slightly more difficult to handle, when once computed for the series of diameters the solution of this term need never be repeated. Values of the second term for the usual diameters are given in table 1 and are shown graphically in figure 1.

Having in mind the uncertainties of formulas for computing flow of water in pipes which inhibit an accuracy closer than 10 per cent under known conditions of pressure and the wide variations in pressure common to average pipe lines in service, it seems entirely unnecessary to

hold the inside diameter to a constant value for the different classes in the same nominal size.

It is proposed to make the outside diameters identical with Class A of A. W. W. A. for all classes in diameters to and including 12 inches. It will be seen from table 2 that the resulting maximum deviation of inside diameter from nominal size is 0.28 inch in the case of 12-inch 150-pound pipe.

For the sizes to and including 12-inch, centrifugally cast pipe will intermember with A. W. W. A. Classes A, B, C, or D, already in the ground, except that some selection may be required in the larger sizes to avoid conflicting extremes of tolerance. This system will, of

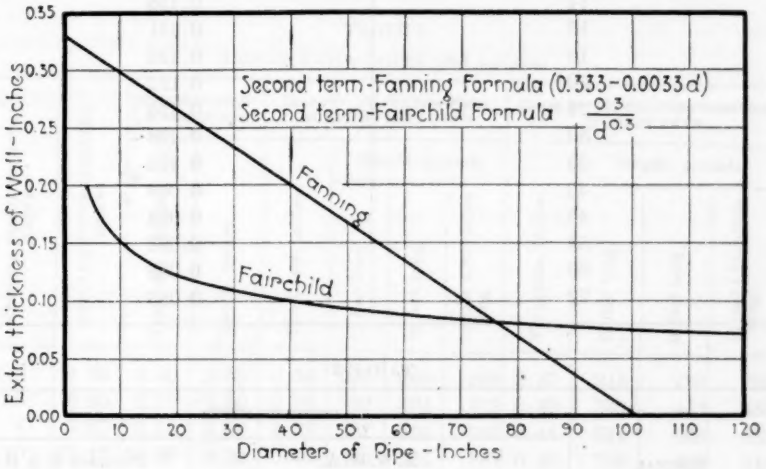


FIG. 1

course, provide complete intermembering of both classes of centrifugally cast pipe in the sizes covered.

In preparing tables from the computed thicknesses, slight deviations, not exceeding 0.01 inch in general, have been made to provide more nearly uniform increments of thickness from one size to the next. In order to provide a sufficient thickness of metal for satisfactory tapping for service lines, the thicknesses have been increased slightly over that computed by the formula for 4 inch pipe in both classes and for 6 inch in the 150 lb. class.

There seemed to be no objection to the acceptance of 12-foot, 16-foot or 5-meter lengths provided the bidder states which length he

proposes to furnish to permit proper allowances for number of joints and other laying conditions involved.

TABLE 1

NOMINAL DIAMETER OF PIPE	VALUE OF $\frac{0.30}{d^{0.3}}$
inches	
4	0.198
6	0.175
8	0.161
10	0.150
12	0.142
14	0.136
16	0.131
18	0.126
20	0.122
24	0.116
30	0.108
36	0.102
42	0.098
48	0.094
54	0.091
60	0.088
72	0.083

TABLE 2

NOMINAL DIAMETER	INSIDE DIAMETER					
	A. W. W. A.				Proposed F. S. B.	
	Class A	Class B	Class C	Class D	150 pounds	250 pounds
inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
4	3.96	4.10	4.04	3.96	4.18	4.10
6	6.02	6.14	6.08	6.00	6.22	6.10
8	8.13	8.03	8.18	8.10	8.29	8.03
10	10.10	9.96	10.16	10.04	10.26	10.06
12	12.12	11.96	12.14	12.00	12.28	12.04

Regarding the omission of bead on the spigot end, it is believed that pipe lines without beads which will stand proof pressures in the open trench, should give no trouble from this source when covered.

The test bar cast separately has been omitted since in centrifugally cast pipe it is necessary to make such tests as may be required on specimens cut from the pipe itself. Test strips cut from the pipe are tested for hardness, moduli of elasticity and rupture, and chemical analyses are made to determine total phosphorous and sulphur.

To provide information looking toward future improvement in the specification and in the product, manufacturers are required to furnish data as to pouring temperatures and analyses showing total carbon, manganese and silicon.

Comment or constructive suggestions applicable to the specification will be appreciated and should be addressed to I. J. Fairchild, Chairman, Pipe, Fittings, Valves, etc., Committee, Federal Specifications Board, Bureau of Standards, Washington, D. C.

TABLE 3

Standard dimensions and weights

NOMINAL INSIDE DIAMETER, INCHES	ACTUAL OUTSIDE DIAMETER, INCHES	DIMENSIONS OF BELLS INSIDE		CLASS I—150 POUNDS PRESSURE, 346 FEET HEAD				CLASS II—250 POUNDS PRESSURE, 576 FEET HEAD			
		Diameter, inches	Depth, inches	Thickness, inches	Weight, pounds			Thickness, inches	Weight, pounds		
					12 feet long	16 feet long	16 feet 4.85 inches long		12 feet long	16 feet long	16 feet 4.85 inches long
4	4.80	5.60	3.50	0.34	201	260	269	0.37	215	280	289
6	6.90	7.70	3.50	0.36	312	402	412	0.40	340	442	453
8	9.05	9.85	4.00	0.38	437	566	580	0.46	514	669	685
10	11.10	11.90	4.00	0.42	586	763	780	0.52	706	922	944
12	13.20	14.00	4.00	0.46	763	993	1,017	0.58	935	1,222	1,252

The text of the specification, dated July 15, 1927, follows:

UNITED STATES GOVERNMENT PROPOSED MASTER SPECIFICATION FOR PIPE, WATER, CENTRIFUGALLY-CAST IRON

I. GENERAL SPECIFICATIONS

The applicable technical and inspection requirements of United States Government General Specifications for Metals, Federal Specifications Board Specification No. 339, are incorporated herein.

II. TYPE, SIZES, CLASSES

1. Pipe shall be furnished in bell and spigot type, with or without bead unless otherwise specified, with lead groove in bell, and in the following classes:

Class I. 150 pound pressure
Class II. 250 pound pressure

2. This specification covers sizes 4 to 12 inches inclusive.

3. Pipe shall be furnished coated, unless cement lined or uncoated pipe is required in the purchase order.

III. MATERIAL AND WORKMANSHIP

All pipe shall be made of cast iron of good quality, and of such character as shall make the pipe strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. Each pipe shall be smooth, free from cold shuts, scale, lumps, blisters, sand holes and defects of every nature which unfit it for the use intended. It shall be straight, and shall be true circles in section with its inner and outer surfaces concentric. No plugging, filling, or burning in will be allowed.

IV. GENERAL REQUIREMENTS

1. Casting. All pipe shall be cast centrifugally in machines. A record of the melting and pouring temperatures of the iron shall be furnished the inspector, when requested.

2. Chemical analysis shall be made by the manufacturer from each heat to determine graphitic and combined carbon or total carbon, if the separate determinations are not available, manganese, phosphorus, sulphur and silicon, and duplicate copies of test reports shall be furnished the inspector. Sulphur shall not exceed 0.10 per cent and phosphorus 0.90 per cent in either ladle or inspection analysis.

3. Annealing. Pipe cast in metal contact molds, after withdrawing from machines, shall be annealed to meet the hardness limits designated under "Inspection and Tests." Pipe cast in sand lined molds, and stripped while showing color of heat, shall be placed in an oven, and shall not be removed therefrom until cooled to 500°F. or under.

4. Lengths. Pipe shall have a laying length of 12 feet, 16 feet or 16 feet 4.85 inches (5 meters). Not more than 10 per cent of cut pipe shall be accepted. Such cut pipe shall be no more than one foot under nominal laying length. Bidder shall state which length he proposes to furnish.

5. Tolerances in diameter. The inside diameters of the bells and the outside diameters of the spigot ends of pipe, exclusive of bead, shall not vary plus or minus from the tabulated dimensions by more than 0.06 inch for pipe 12 inches and less in nominal diameter.

6. Tolerances in thickness. The tolerances in thickness, plus or minus, hall not exceed those listed below.

NOMINAL DIAMETER	TOLERANCE, PLUS OR MINUS
inches	*inches*
4	0.04
6	0.045
8	0.05
10	0.055
12	0.06

For all sizes of pipe, tolerances not exceeding 0.02 inch additional to above will be allowed for spaces not exceeding 8 inches in length in any direction.

7. Tolerance in weight. The weight of no single pipe shall be less than the nominal weight by more than 5 per cent.

8. Cleaning. All pipe shall be thoroughly cleaned, and any rough spots in bells or on spigot ends shall be ground, before coating or lining.

9. Physical requirements. Pipe shall conform to physical requirements as given in Section VI–5, 6 and 7.

10. Coating. Unless otherwise specified all pipe shall be completely coated inside and out with coal-tar pitch varnish, to which sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, not "tacky" and not brittle.

11. Cement mortar lining. (*a*) When required in the contract or purchase order, pipe shall be lined with cement mortar. No coating will be applied to the outside unless specifically provided in the contract or order. Cement shall be standard Portland, complying in all respects with the requirements of United States Government Master Specification No. 1 for Portland Cement in effect on date of invitation for bids. Sand shall be clean, free from organic matter, loam, and other foreign material. It shall be screened through a screen with not less than 12 meshes per inch.

(*b*) Unless otherwise specified mortar shall be approximately three parts of cement to one part of sand by volume, and thoroughly mixed in a power mixer, using only sufficient water to permit of proper distribution of mixture in pipes. Mortar shall be promptly used after mixing and no mortar shall be used which has attained its initial set.

(*c*) Cement mortar lining shall be smooth, continuous, completely adherent and reasonably free from check cracking. All excess mortar shall be removed from the bottom of the bell. No pipe shall be shipped until lining is thoroughly hard.

(*d*) Thickness of linings shall be $\frac{1}{8}$ inch $\pm \frac{1}{16}$ inch for all sizes to and including 12 inch.

12. Weighing. Each length ofpipe shall be weighed and the weight plainly marked on the pipe. Coated pipe shall be weighed after coating. Cement lined pipe shall be weighed before lining and the mark shall be placed on the outside surface.

13. Handling. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material shall be placed in the pipes during transportation, or at any time after they have been coated.

14. In addition to the weight being painted on the pipe as previously specified, each pipe shall have distinctly cast or stamped into the metal on the face or outside surface of the bell the manufacturer's mark, and the year in which the pipe was cast. When so specified in the invitation for bids each pipe shall also have cast upon it or stamped into the metal a designated symbol.

V. DETAIL REQUIREMENTS

The pipe shall accurately conform to the dimensions given in table 3.

VI. INSPECTION AND TESTS

1. The contractor shall furnish the inspector, free of cost, such facilities as may be necessary for the performance of his work.

2. The inspector shall have free access at all times to all parts of any manufacturing plant which concern the manufacture of the material ordered.

3. All handling of material, sampling, preparation of test specimens, and testing thereof, except purchaser's chemical analysis, shall be performed or furnished by the contractor without expense to the Government. Where the manufacturer has no facilities for making tests or analyses required, they will be made at some suitable place in the vicinity, at the contractor's expense, and in the presence of the inspector.

4. All pipe shall be subjected to a careful surface inspection, and hammer and rolling tests. All bells shall be tested by circular gages and no pipe will be accepted which is deficient in joint room.

5. Tests of material. From each 300 lengths of pipe, or fraction thereof, of each size in the contract or order, one length of pipe shall be selected by the inspector before coating. From each sample pipe there shall be cut and machined one test strip 12 inches long, 0.50 inch deep, and the full thickness of the shell in width. This shall be tested as a beam (with machined surfaces top and bottom) on supports 10 inches apart with load applied at two points $3\frac{1}{2}$ inches from the supports. The strip shall be accurately calipered at point of rupture and stress calculated by the formula

$$S = \frac{Plc}{6I}$$

The secant modulus of elasticity at the breaking load, shall be calculated by the formula

$$E = \frac{23Pl^3}{1296Iy}$$

In these formulas S = modulus of rupture
E = modulus of elasticity
P = total load
l = length of span
c = distance to extreme fibre
I = moment of inertia
y = center deflection at load P

The secant modulus of elasticity shall not exceed 15,000,000 pounds per square inch with a corresponding modulus of rupture not less than 40,000 pounds per square inch or as an alternate, the secant modulus of elasticity shall not exceed 10,000,000 pounds per square inch with a corresponding modulus of rupture not less than 35,000 pounds per square inch.

6. Hydrostatic tests. Each length of pipe shall be subjected to a proof of 500 pounds hydrostatic pressure, and while under pressure shall be subjected to a hammer test. A pressure gage shall be used to show the pressure applied, and the pipe shall be under test pressure at least one-half minute. Any pipes showing defects by leaking, sweating, or otherwise, shall be rejected.

7. Rockwell tests. Upon the machined edges of each test strip there shall be made at well distributed points not less than 3 determinations, using a 1.59 mm. ($\frac{1}{16}$ inch) ball and 100 kgm. load. The average Rockwell No. shall not exceed 95. An additional determination shall also be made for pipe cast in metal contact machines, upon the outside of each pipe, using a portable type machine. The equivalent Rockwell No. for the exterior shall not exceed 95.

8. Chemical analyses. In addition to such analyses as are required to be made by the contractor, the inspector may obtain samples for chemical analysis from finished material representing each melt. The inspector may have samples for chemical analysis taken from test strips, or from any part or parts of the material concerned, provided the serviceability of the part or parts is not destroyed. The sample taken for chemical analysis shall be of sufficient size to permit five analyses to be made.

9. Rehearing. In case of dissatisfaction with results of the chemical analysis, the contractor may make claim for a rehearing, in which case the chemical composition shall be determined by a Government laboratory. Part of any sample taken for chemical analysis shall be furnished the contractor if he so requests the inspector at the time the sample is taken.

10. Retests. If any test specimen shows defective machining or obvious lack of continuity of metal it may be discarded and replaced by another specimen selected by the inspector. If any of the test specimens selected fails to meet the requirements specified and the purchaser permits a retest, at least two additional replacement specimens shall be selected by the inspector, both of which shall meet requirements.

VII. MARKING OF SHIPMENTS

Marking of shipments shall be in accordance with best commercial practice unless otherwise specified.

VIII. NOTES

1. Invitations for bids should state the number of linear feet of pipe desired and payment should be made on a per foot basis. No bids should be accepted on a tonnage basis.

2. If special symbol is desired (see Section IV-14) it shall be so stated or indicated in the invitation for bids. If not so stated, it will be assumed that none is desired.

3. For lines for water known to cause serious tuberculation it is recommended that pipe be not coated, and that it be lined with cement mortar.

4. Cast iron water pipe produced other than by the centrifugal method should not be purchased under this specification.

5. Centrifugally-cast iron pipe of lighter weight than specified herein, when required for exhaust or other low pressure lines, should be purchased on a separate specification.

6. When linings other than those specified in section IV–11 (*d*) are required, it should be so stated in the purchase order.

ZEOLITE WATER TREATMENT IN A LARGE CENTRAL HEATING PLANT[1]

By Alfred H. White;[2] J. H. Walker;[3] Everett P. Partridge;[4] and Leo F. Collins[5]

This paper describes a zeolite water treatment system in the Beacon Street heating plant of The Detroit Edison Company. It gives the results of some extensive preliminary laboratory investigations, carried on at the University of Michigan, to determine the possibilities of the removal of carbon dioxide from a zeolite-treated water by means of sulphuric and phosphoric acids. Some actual operating results are also included.

The matter of feedwater treatment is of extreme importance in a central heating plant. Recent developments in boiler design and firing methods have made possible very great increases in rates of driving, with consequent reductions in investment costs. Most of these developments have originated in electrical generating stations using distilled water or at least a high percentage of recirculated water. In a central heating plant the advantages of high steaming rates are at least equally great, but the necessarily large amount of make-up water in such a plant (very little condensate being returned from the consumers' buildings) makes the successful attainment of such steaming rates very difficult. The feedwater treatment thus becomes of primary importance and if, through the production of a better water, any particular method of treatment makes higher steaming rates possible, then the reduction thus brought about in the entire plant investment far over-balances any possible increased cost of installing and operating the treating system.

[1] Presented before the Boiler Feed Water Studies session, Chicago Convention, June 8, 1927.

[2] Professor of Chemical Engineering, University of Michigan, Ann Arbor, Mich.

[3] Assistant to the Chief Engineer, The Detroit Edison Company, Detroit, Mich.

[4] Fellow in Chemical Engineering, University of Michigan, Ann Arbor, Mich.

[5] Chemist, The Detroit Edison Company, Detroit, Mich.

The primary consideration in the selection of a treating system for this heating plant was that it produce as nearly a scale-free water as possible. A deposit of scale of even eggshell thickness in boiler tubes which are directly exposed to severe radiant heat will so impede heat transfer as to cause overheating and failure of the tube wall; and it is the unfortunate characteristic of the worst scale forming materials that their decreasing solubility with increasing temperature causes them to precipitate on these hottest tube walls.

CHOICE OF A TREATMENT SYSTEM

The Beacon Street heating plant is the newest of the four plants which supply steam for heating in the central business district of Detroit. It is designed to contain, eventually, twelve boilers of 41,500 square feet of surface, each, and capable of being operated at 300 per cent of rated capacity—a steam output of 406,000 pounds per hour per boiler. These boilers, by he way, are the largest yet built as to evaporating surface, though not as to steam output.

The make-up water is taken from the city water mains. The Detroit water supply is taken from the Detroit River at the foot of Lake St. Clair and is filtered. A typical analysis (March, 1926) is as follows:

	parts per million
CO_2 (free)	1.8
SiO_2	6.4
Fe_2O_3	2.0
Ca	25.7
Mg	7.3
Na and K	Not determined
HCO_3	75.6
CO_3	0.0
SO_4	31.1
Cl	7.7
Total solids (by evaporation)	121.0

This is a rather soft water and external treatment had never been considered necessary in the existing heating plants, operated at lower steaming rates, although internal treatment with sodium carbonate had been used for several years.

Consideration was given to several methods of treatment before the selection of zeolite was finally made. Internal treatment with

sodium carbonate, using the control methods devised by R. E. Hall[6] was one possibility. It had recently been used with some success in the older and smaller heating plants and has the advantage of requiring very little equipment. However, it produces large quantities of carbonate sludge in the boiler, does not entirely prevent the formation of certain silicate scales, and produces a high caustic alkalinity in the boiler.

Tri-sodium phosphate had also been used successfully, but it is open to similar objections. The resulting caustic alkalinity is somewhat lower than with sodium carbonate treatment, although at the operating pressure of 150 pounds the difference is not as great as at higher pressures.

Barium salts because of their poisonous nature were ruled out as a matter of public policy due to the fact that steam supplied by the plant is used for cooking purposes.

The hot process lime and soda system was carefully considered and its choice would have been a conservative decision. To the engineers responsible for the design and operation of the plant it did not appear, however, that this treatment would invariably produce a scale-free water; and the hot sedimentation tanks which are a necessary part of such a system would have been costly and awkward, since the plant is designed for an ultimate output of 4,000,000 pounds of steam per hour with about 90 per cent make-up water.

The zeolite system as finally chosen is open to the theoretical objection that it does not remove the dissolved solids but merely converts them to more soluble salts, thus causing high concentrations of solids in the boiler and requiring a large amount of blow-off. Another objection is that with a bicarbonate water such as that in Detroit the sodium bicarbonate produced by the treatment unless removed by an after-dose of acid would ultimately cause a high caustic alkalinity in the boiler. As a means of preventing scale formation, however, it appeared that the zeolite system would be certain of results and operating experience has confirmed this conclusion. With the calcium and magnesium almost totally removed, the potential scale-forming elements are largely disposed of and the possibility of the small residue of these materials depositing as sulphate scale is probably prevented by the presence of sufficient carbonate ions, if Dr. Hall's conclusions are correct.

[6] A Physico-Chemical Study of Scale Formation and Boiler Water Conditioning. Bulletin No. 24, Carnegie Institute of Technology.

The large amount of blow-down is prevented from being a serious source of heat loss by the continuous extraction of a small amount of water which is passed through a heat exchanger where the heat is transferred to the colder supply water. The waste of the water itself however cannot be economically prevented.

REASONS FOR ACID TREATMENT

The high caustic alkalinity in the boiler resulting from the use of a zeolite system with a water which is high in bicarbonates demands consideration of the possibility of embrittlement of the boiler steel.[7] Although no attempt was made to pass judgment upon this as yet unsettled point, it was thought prudent to add the required quantity of inhibiting sulphate ions suggested by Professor Parr and others. For this reason the plan was adopted of treating the water after passage through the zeolite bed with a carefully graduated dose of sulphuric acid.

There was a further requirement imposed upon the treating system which would be met by the use of this acid feed. With a bicarbonate water the steam leaving the boiler is ordinarily contaminated with carbon dioxide and one of the objects sought was the reduction of this gas content. The slow corrosion which has occasionally been observed in the pipes and radiators of consumers' heating systems has been thought to be partially due to the presence of this gas along with oxygen and there is some evidence to support this view.[8] The addition of acid to the zeolite-treated water would serve to liberate an equivalent amount of carbon dioxide, and if the water were passed through a deaerator before going to the boiler the free carbon dioxide would be removed along with the oxygen. Some of the remaining bicarbonate would also be broken up. The addition of sulphuric acid is more effective in increasing the sulphate-carbonate ratio than would be the addition of a sulphate salt because it removes carbonate ions as well as adding sulphate ions; and although the primary purpose of the acid is the inhibition of caustic embrittlement, its use also makes it possible to reduce the carbon dioxide

[7] The Cause and Prevention of Embrittlement of Boiler Plate. By S. W. Parr and F. G. Straub. Bulletin No. 155, Engineering Experiment Station, University of Illinois.

[8] Reports of Corrosion Committee, Proceedings of the National District Heating Association, 1924 and 1925.

content of the resulting steam approximately in proportion to the amount of acid fed. The use of acid following a zeolite treatment is not new, but the method of application possesses some novel features and it has probably not been used heretofore on such a large scale nor accompanied by quantitative studies of its effects.

The limits to the amount of acid to be fed could not be set clearly from theoretical considerations. There were two points to be guarded against in the introduction of sulphuric acid:—one the danger of corrosion due to an acid water, and the other the possible deposition of sulphate scale if the concentration of the carbonate was reduced to too low a point. The use of phosphoric acid offered some attractive possibilities as a supplement to sulphuric acid because of its lesser corrosive action and the flocculent nature of calcium phosphate which does not form a hard scale. The obvious disadvantage of phosphoric acid lay in its higher cost.

EXPERIMENTS ON THE EFFECT OF ACIDIFICATION AND ON ELIMINATION OF CO_2

Experimental laboratory work was first undertaken on waters containing $Ca(HCO_3)_2$, and the changes in such waters on boiling subsequent to additions of varying amounts of acid were studied. Similar tests were made on water which was of the type of Detroit city water after zeolite treatment; that is, water in which sodium bicarbonate is the main salt in solution. Since this paper discusses the process as actually installed in the Beacon Street plant, the only experimental data given here deal with tests on water similar to that coming from a zeolite softener. The water was treated with various amounts of acid and then heated to determine the amount of carbon dioxide evolved and the resultant changes in the acidity of the water. The laboratory tests were made in glass flasks in which the water was kept at boiling temperature, at atmospheric pressure, with the volume of water kept constant. In a boiler this constancy of volume is maintained by the introduction of new water but the adoption of this procedure in the laboratory would have prevented the study of the progressive changes which occur when a definite initial mass of water is boiled. The figures thus obtained are not strictly comparable with those obtained in boiler practice. They do, however, afford a valuable indication of the results to be expected in actual operation and the conclusions drawn from them have been largely borne out in practice.

The laboratory process approximates the conditions existing in an open feed-water heater intended for deaeration. Steam at atmospheric pressure is passed through the water being tested, which is contained in a flask jacketed in boiling water to prevent undue condensation. The steam leaving the water carries with it carbon dioxide. By passing this steam through a condenser and discharging the condensate into barium hydroxide, the amount of carbon dioxide removed from the water was found for successive increments of steam used. The actual technique is somewhat involved, in order to guard against loss of carbon dioxide and the influence of the small amount of that gas present in the atmosphere. Since the laboratory apparatus does not allow as intimate contact between the steam and hot water as does a commercial deaerator, the actual results in the plant were somewhat better, as will be shown later.

One part of the investigation was conducted, before the zeolite system was finally chosen, on an artificial water of approximately the same concentration of sodium bicarbonate as zeolite-treated Detroit water. This water contained 70 parts per million of combined carbon dioxide. The rate of removal of the carbon dioxide was first determined for samples acidified to varying degrees with tenth-normal sulphuric acid, and then the curves for samples treated with the same amounts of tenth-normal phosphoric acid were obtained.

Another part of the experimental work, conducted after the plant was in operation, was to determine the rate of evolution of carbon dioxide from a water which had been through the zeolite softener and had been partially acidified with sulphuric acid in the regular feed-water treatment of the Beacon Street plant. It was desired to know the ultimate possibilities of the breaking up of sodium bicarbonate by continued steam treatment.

The hydrogen-ion concentration of the water was measured in each case, first, after the addition of the acid, and, second, after the removal of carbon dioxide had been carried nearly to completion. LaMotte colorimetric standards were used for this work.

CO_2 REMOVAL AND FORMATION OF NaOH

The carbon dioxide removal curves for both parts of the investigation are shown in the accompanying figures. Figure 1 shows the actual experimental results, plotted as parts per million of carbon dioxide removed against amount of steam passed through the water,

expressed in per cent of the amount of the water sample. The curves of figures 2 and 3 show the parts per million of combined carbon dioxide left in the water for any per cent of steam passed through it. Figures 1 and 2 refer to the samples of treated water from the Beacon

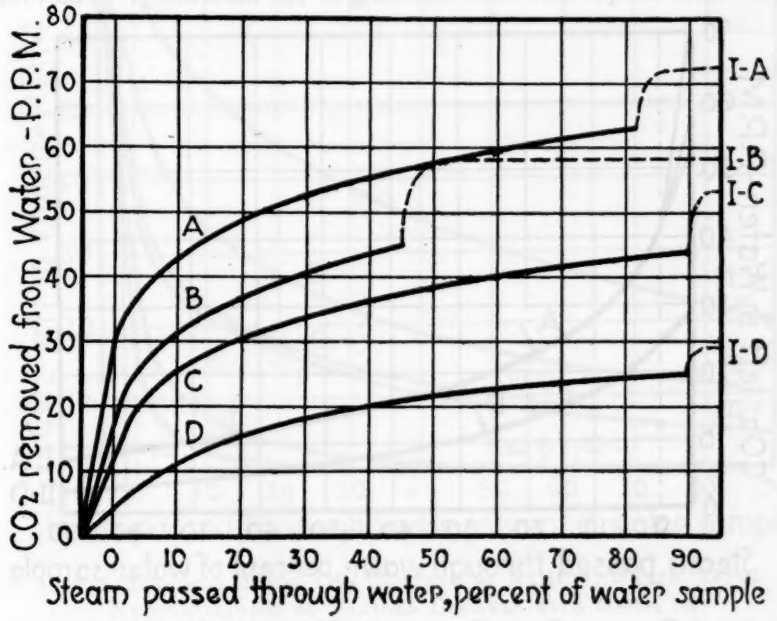


FIG. 1. LABORATORY TESTS ON THE REMOVAL OF CO_2 FROM THE ZEOLITE-TREATED AND PARTIALLY NEUTRALIZED FEED WATER OF THE BEACON STREET PLANT

The parts of the curves to the left of the zero point show the elimination of CO_2 while the water was being heated to the boiling point. The dotted lines indicate the changes caused by the addition of excess acid near the end of a run for the purpose of liberating all of the CO_2 remaining in the water.

Curves A, B, and C were made from the same sample of partially neutralized but not deaerated water, which had lost part of its CO_2 by standing in the air one week in the case of B, and two weeks in the case of C.

Curve D was made on water which was taken from the outlet of the deaerator at the Beacon Street Plant.

Street plant and figure 3 to the artificial sodium bicarbonate water prepared in the laboratory.

Four curves are shown in figure 1. Of these, the upper three represent the rate of removal of carbon dioxide from the zeolite-softened

and acidified, but not deaerated, water taken from the Beacon Street plant. Curve A was made immediately upon receipt of the water sample, when the total carbon dioxide content was 72.5 parts per million. Curve B was made after an interval of a week, during which the water sample had been standing in the laboratory. The total

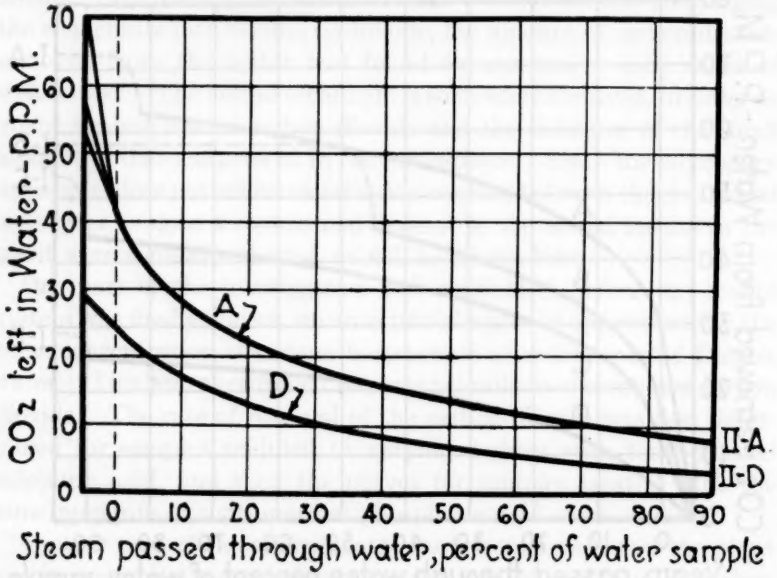


FIG. 2. RESIDUAL TOTAL CONTENT OF CO_2 OF THE ZEOLITE-TREATED AND PARTIALLY ACIDIFIED WATER OF THE BEACON STREET PLANT AS SHOWN ON LABORATORY TESTS

These curves are from the same data as those of figure 1.

Curves A, B, and C of figure 1 fall so closely together that they are combined as one curve to the right of the vertical zero line. These represent the partially acidified water which had been allowed to lose varying proportions of its inital CO_2 by standing in the air. Curve D represents the changes in the water which was taken from the outlet of the deaerator.

$$2NaHCO_3 + xH_2O \rightleftarrows Na_2CO_3 + CO_2 + (x + 1)\,H_2O$$
$$Na_2CO_3 + xH_2O \rightleftarrows 2NaOH + CO_2 + (x - 1)\,H_2O$$

carbon dioxide content at this time had dropped to 58.4 parts per million. Curve C was determined after the water had been standing in the laboratory a second week. At this time the water contained 53.0 parts per million total carbon dioxide. By referring to figure 2 it will be seen that the three curves from figure 1, when plotted as

residual carbon dioxide in the water, fall closely together in Curve A. This seems to point conclusively to the fact that the free carbon dioxide dissolved in water, whether derived from equilibrium with

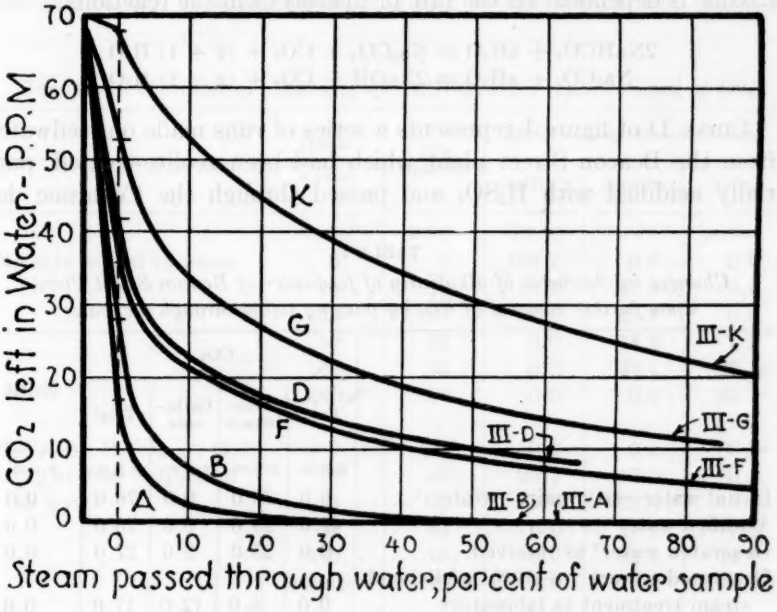


FIG. 3. RESIDUAL TOTAL CO_2 CONTENT OF $NaHCO_3$ WATER, AFTER NEUTRALIZATION TO VARIOUS DEGREES WITH H_2SO_4 OR H_3PO_4 AND DEAERATION TO VARIOUS DEGREES IN LABORATORY APPARATUS

The parts of the curves to the left of the vertical zero line show the elimination of CO_2 while the water was being heated to the boiling point.

CURVE NUMBER	ACID USED	N/10 ACID PER 500 CC. WATER	PER CENT OF COMPLETE NEUTRALIZATION	pH OF WATER ON ADDITION OF ACID	pH OF WATER AFTER CO_2 REMOVAL
		cc.	*per cent*		
A	H_2SO_4	7.5	94.0	5.7	8.75
B	H_3PO_4	11.25	94.0	6.4	8.5
D	H_3PO_4	7.5	62.5	6.65	*
F	H_2SO_4	5.0	62.5	6.3	*
G	H_3PO_4	5.0	41.6	6.85	*
K	None	None	0.0	8.25	*

* pH above 8.8 beyond range of available indicator standards.

the carbon dioxide of the atmosphere, or from the neutralization of bicarbonate by the addition of acid, is removed very rapidly on heating the water, and that the subsequent rate of removal of carbon dioxide is dependent on the rate of hydrolysis in the reactions:

$$2NaHCO_3 + xH_2O \rightleftarrows Na_2CO_3 + CO_2 + (x + 1)\ H_2O$$
$$Na_2CO_3 + xH_2O \rightleftarrows 2NaOH + CO_2 + (x - 1)\ H_2O$$

Curve D of figure 1 represents a series of runs made on feedwater from the Beacon Street plant which had been zeolite-treated, partially acidified with H_2SO_4 and passed through the Cochrane de-

TABLE 1

Changes in character of alkalinity of feedwater of Beacon Street Plant upon further removal of CO_2 by passing steam through the water

	CO_2				NaOH
	Free	Bicarbonate	Carbonate	Total	
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Initial water—city mains (winter)[1]	6.0	70.0	0.0	76.0	0.0
Acidified water[1]	47.0	29.0	0.0	76.0	0.0
Deaerated water[2] as received	0.0	25.0	2.0	27.0	0.0
Deaerated water[2] + 10% additional steam treatment in laboratory	0.0	5.0	12.0	17.0	0.0
Deaerated water[2] + 20% additional steam treatment in laboratory	0.0	0.0	13.5	13.5	1.8
Deaerated water[2] + 100% additional steam treatment in laboratory	0.0	0.0	2.5	2.5	21.8

[1] From data obtained by The Detroit Edison Company.

[2] From the laboratory tests.

aerator in accordance with present practice. The total carbon dioxide content of this deaerated water was 27.0 parts per million. Since the water was alkaline to phenolphthalein, none of this was present as free carbon dioxide. In figure 2 the same results are expressed in curve D. It will be seen from this group that further removal of carbon dioxide from the deaerated water is still fairly rapid for the first part of the curve, the residual carbon dioxide in the water being decreased from 27 to 17 parts per million for 10 per cent additional steam used. Thus it appears that by supplementing the present deaerating process by passing additional steam through the water, the carbon dioxide could be removed to a greater degree.

In the following tables, table 1 shows the condition of the water at the various steps in the present treatment and possible further treatment with excess steam. The formation of caustic soda took place in the laboratory experiments during the steam treatment. In the

TABLE 2

Changes in character of alkalinity of $NaHCO_3$ water upon removal of CO_2

AMOUNT OF ACID TREATMENT	STEAM THROUGH WATER	CO_2 REMOVED	RESIDUAL ALKALINE SUBSTANCES		
			$NaHCO_3$	Na_2CO_3	NaOH
	per cent	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
No acid added to water	0	0	133.7	0.0	0.0
	10	17	68.8	41.0	0.0
	25	27	30.6	65.1	0.0
	50	39	0.0	74.6	7.3
	100	50	0.0	48.1	27.3
	Infinite*	70	0.0	0.0	63.7
H_2SO_4 or H_3PO_4 = 43.8 p.p.m. free CO_2 added to water	0	(35)	50.0	0.0	0.0
	10	50	26.3	15.0	0.0
	25	56	3.4	29.4	0.0
	50	61	0.0	21.7	7.5
	100	65	0.0	12.1	14.7
	Infinite*	70	0.0	0.0	23.8
H_3PO_4 = 65.6 p. p. m. free CO_2 added	0	42	8.4	0.0	0.0
	10	61	8.4	0.0	0.0
	25	68	0.0	4.8	0.4
	50	70	0.0	0.0	4.0
H_2SO_4 = 65.6 p. p. m. free CO_2 added	0	52	8.4	0.0	0.0
	10	68	0.0	4.8	0.4
	25	69	0.0	2.4	1.9
	50	70	0.0	0.0	4.0

* Calculated for complete decomposition by hydrolysis.

Results of laboratory tests made on a sodium bicarbonate solution containing 133.7 parts per million $NaHCO_3$ equivalent to 70.0 parts per million CO_2. Tests made at atmospheric pressure by passing various percentages by weight of steam through the water maintained at the boiling point.

plant, however, it takes place only in the boiler. The result is, however, merely dependent on the time of reaction and the continuous removal of carbon dioxide. Pressure is not necessary.

The effect of the addition of different quantitites of sulphuric and

phosphoric acids as well as duration of boiling on a water containing only sodium bicarbonate is shown in table 2, figure 3 and figure 4. The rate of removal of CO_2 is studied most conveniently in figure 3 which shows in curve A that after the addition of sulphuric acid in amount sufficient to liberate 65.6 of the 70 parts per million

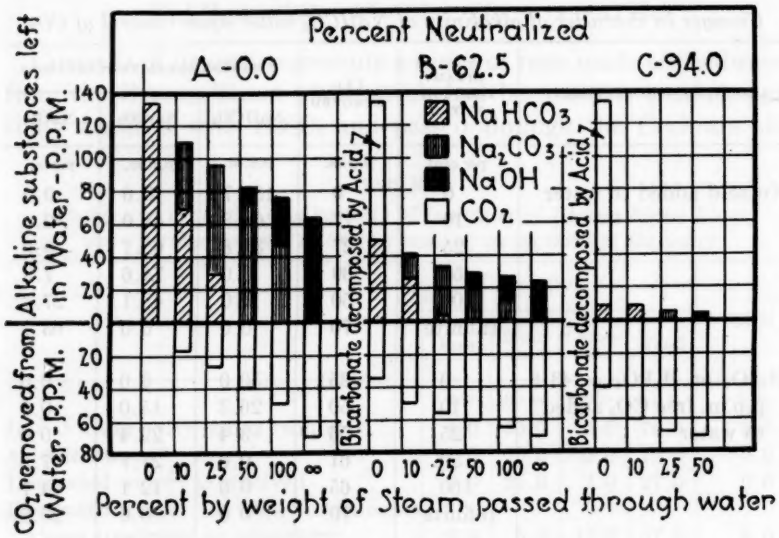


FIG. 4. CHANGES, UPON REMOVAL OF CO_2, OF CHARACTER OF ALKALINITY OF WATER CONTAINING $NaHCO_3$ AFTER NEUTRALIZATION TO VARIOUS DEGREES

These graphs are from the same data as figure 3. The columns marked with the infinity symbol represent the theoretical condition after complete removal of CO_2.

$$NaHCO_3 + H_2SO_4 \rightleftarrows NaHSO_4 + H_2O + CO_2$$
$$NaHCO_3 + NaHSO_4 \rightleftarrows Na_2SO_4 + H_2O + CO_2$$

$$NaHCO_3 + H_3PO_4 \rightleftarrows NaH_2PO_4 + H_2O + CO_2$$
$$NaHCO_3 + NaH_2PO_4 \rightleftarrows Na_2HPO_4 + H_2O + CO_2$$
$$NaHCO_3 + Na_2HPO_4 \rightleftarrows Na_3PO_4 + H_2O + CO_2$$

CO_2 the amount of CO_2 left in the water when it reached the boiling point had dropped to 17 parts and after 5 per cent steam had passed through the residual CO_2 was only 4 parts. Practically complete removal of the CO_2 came when 40 per cent of steam was passed through the water.

The changes in alkalinity of the water with partial neutralization

and subsequent boiling are best followed in figure 4. It will be noted that the laboratory bicarbonate water contains 133.7 p.p.m. $NaHCO_3$ and no other compound than $NaHCO_3$ but that after it has been heated to boiling and 10 per cent by volume of steam has been passed through, that 17 p.p.m. of CO_2 have been evolved and that the water, whose volume has remained constant, now contains 41.0 p.p.m. $NaHCO_3$ and 68.8 $NaHCO_3$. After 50 per cent by volume of steam has been blown through the water, the $NaHCO_3$ has all been broken up and there is left 74.6 p.p.m. Na_2CO_3 and 7.3 NaOH. If the process were continued long enough, there would be only NaOH left in the water.

The effect of partial acidification is also shown in figure 4. The CO_2 displaced by the acid is evolved promptly and the residual $NaHCO_3$ is decomposed at the same rate as before. The effect of acid in cutting down the quantity of NaOH which can appear in the water is shown quite strikingly.

COMPARISON OF H_2SO_4 AND H_3PO_4 AS ACIDIFYING AGENTS

The curves in figure 3 show that H_2SO_4 and H_3PO_4 have substantially the same value for neutralizing $NaHCO_3$ provided only two of the three hydrogen atoms of H_3PO_4 are considered as being available for this purpose. This relation may be explained by considering the reaction of each of these acids with sodium bicarbonate, the latter substance being in excess.

The sulphuric acid reaction may be written in two steps:

$$NaHCO_3 + H_2SO_4 \rightleftarrows NaHSO_4 + H_2O + CO_2$$
$$NaHCO_3 + NaHSO_4 \rightleftarrows Na_2SO_4 + H_2O + CO_2$$

Both reactions will always go substantially to completion, since $NaHSO_4$ is stable only in solutions of low pH, while $NaHCO_3$ produces a pH greater than 8.0 even in extremely dilute solution.

With phosphoric acid a similar series of reactions take place.

$$NaHCO_3 + H_3PO_4 \rightleftarrows NaH_2PO_4 + H_2O + CO_2$$
$$NaHCO_3 + NaH_2PO_4 \rightleftarrows Na_2HPO_4 + H_2O + CO_2$$
$$NaHCO_3 + Na_2HPO_4 \rightleftarrows Na_3PO_4 + H_2O + CO_2$$

In this case, the first sodium salt formed is stable at a pH of 4.5 and, therefore, cannot exist in the presence of excess $NaHCO_3$ with its much higher pH. The second sodium salt, however, the di-sodium phosphate, is stable at a pH of approximately 9.0 and therefore

will not react with an excess of sodium bicarbonate. The third hydrogen atom of phosphoric acid, is, therefore, not available for decomposition of sodium bicarbonate.

When compared on this basis the acids act so similarly that a difference hardly appears when plotted on the scale of figure 3 which gives a few representative curves. It may be noted that curve A obtained with H_2SO_4 shows a more rapid reaction in the first stages than curve B with H_3PO_4. This may probably be ascribed to a slight lag in the second reaction of mono-sodium phosphate with sodium bicarbonate.

In the reaction of phosphoric acid with sodium bicarbonate there exists an equilibrium between the various salts. For the sake of simplicity, the transition from salt to salt has been assumed to be abrupt. Actually, at a pH of 4.5 only mono-sodium phosphate is present, and at a pH of 9.0 only di-sodium phosphate is present. At any intermediate pH, however, both salts are in equilibrium, while below 4.5 mono-sodium phosphate is in equilibrium with free acid, and above 9.0, di-sodium phosphate is in equilibrium with tri-sodium phosphate.

Since only two of the three acid hydrogen atoms of phosphoric acid are available for neturalization of sodium bicarbonate and since tenth-normal acids are made up to contain one-tenth of a gram of formula hydrogen per liter, it requires 50 per cent more phosphoric acid than sulphuric acid of a given normality to achieve the same results. Calculated on a molecular rather than a normal basis, equimolecular concentrations of phosphorie acid and sulphuric acid will have equal neutralizing effects on sodium bicarbonate. Since the formula weights of H_3PO_4 and H_2SO_4 happen to be identical, it follows that one pound of 100 per cent phosphoric acid will be equal to one pound of 100 per cent sulphuric for neutralization of a bicarbonate solution. Sulphuric is much the cheaper acid and therefore there is, so far, no reason for using phosphoric. If, however, we consider the pH produced in a bi-carbonate solution by addition of a given amount of sulphuric acid, and compare it with the pH produced by an amount of phosphoric acid of equal neutralizing effect, the advantage of phosphoric acid in this respect becomes apparent.

This comparison may be made by reference to the data accompanying figure 3. Curve A represents the removal of carbon dioxide from the sodium bicarbonate solution when neutralized with 94 per cent of the theoretical amount of tenth-normal sulphuric acid, while

curve B shows the CO_2 removal for the corresponding amount of phosphoric acid. It will be noted that the initial pH produced by the addition of 7.5 cc. of tenth-normal sulphuric acid was 5.7, while that produced by the effective equivalent of tenth-normal phosphoric acid, 11.25 cc., was 6.4. In both cases after practically complete removal of carbon dioxide the pH had shifted back to a high value, 8.75 for the solution treated with sulphuric acid and 8.5 for the solution treated with phosphoric acid. The higher initial pH and lower final pH produced by the phosphoric acid is due to the buffer action of the sodium salts of phosphoric acid, commonly utilized in making solutions of standard pH. Addition of acid or alkali to an equilibrium between sodium salts of phosphoric acid is partially offset by a

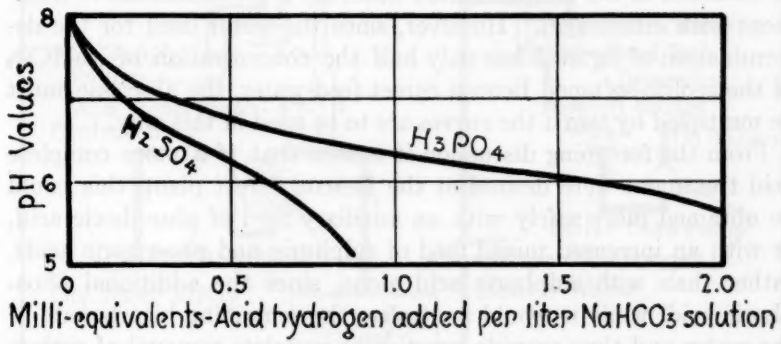


FIG. 5. EFFECT OF ADDITIONS OF H_2SO_4 AND H_3PO_4 ON pH OF WATER CONTAINING $NaHCO_3$

readjustment of the ionic equilibrium in the direction of constant hydrogen-ion concentration.

The ideal boiler water should be neither acid nor alkaline. If enough H_2SO_4 is added to a bicarbonate water to release all of the CO_2 the water will be acid and corrosive as it goes to the feed-water heater though it will be neutral as it comes from it. If too little H_2SO_4 is added, the water will go from the feed-water heater to the boiler containing $NaHCO_3$. By using H_3PO_4, the bicarbonate content may be neutralized completely with the production of an only slightly acid pH in the water going to the feed-water heater. Furthermore, any accidental slight excess of phosphoric acid will be much less harmful than a similar excess of sulphuric acid, since the buffer action of the sodium phosphate salts tends to counteract the decrease in pH.

The actual pH values produced by adding various amounts of sulphuric or phosphoric acid to a sodium bicarbonate solution were determined on a water of approximately one-half the concentration with respect to sodium bicarbonate of the zeolite-treated water of the Beacon Street plant. This would correspond roughly to the plant feed-water after the present acid treatment if it were allowed to lose its excess free carbon dioxide to the air. Figure 5 represents the plot of pH of the solution after addition of acid against the amount of acid added expressed as milli-equivalents per liter. The buffer effect of the sodium salts of phosphoric acid is evident in the relative amounts of phosphoric and sulphuric acid required to produce a given pH. These data allow a prediction of the pH which would be obtained in the zeolite-treated water for a given amount of treatment with either acid. However, since the water used for the determination of figure 5 has only half the concentration of $NaHCO_3$ of the zeolite-softened Beacon Street feed-water, the abscissae must be multipled by two if the curves are to be used in this way.

From the foregoing discussion it is seen that, if a more complete acid treatment were desired at the Beacon Street plant, this could be obtained more safely with an auxiliary feed of phosphoric acid, or with an increased mixed feed of sulphuric and phosphoric acids, rather than with sulphuric acid alone, since the additional phosphoric acid, while it would neutralize the remaining bicarbonate of the water and thus provide practically complete removal of carbon dioxide in the deaerator and would decrease the concentration of caustic in the boiler, would nevertheless not lower the pH of the water at any point in the system as much as would an equivalent amount of additional sulphuric acid.

ADVANTAGES OF PHOSPHORIC ACID IN PREVENTION OF CAUSTIC ALKALINITY

A solution of $NaHCO_3$, on boiling with continuous removal of the CO_2, breaks down into Na_2CO_3 and H_2O, which ultimately hydrolyzes into NaOH and CO_2. It has been noted that when H_3PO_4 is added to $NaHCO_3$, the reaction stops with Na_2HPO_4 in equilibrium with $NaHCO_3$ and that, therefore, only two-thirds of the available hydrogen has reacted. If now this solution of $NaHCO_3$ and Na_2HPO_4 be boiled with continuous removal of CO_2, the NaOH formed will react with the Na_2HPO_4 according to the reaction.

$$NaOH + Na_2HPO_4 \rightleftarrows Na_3PO_4 + H_2O$$

So long, therefore, as undecomposed Na_2HPO_4 is present, only a small amount of caustic alkalinity can build up in the boiler. There will be slight alkalinity due to the hydrolysis of the Na_3PO_4, but this will not increase with concentration of the salts in the water as does the concentration of NaOH due to decomposition of Na_2CO_3, because in the hydrolysis of Na_3PO_4 both the basic and acid reaction products stay in solution and continue to influence each other while in the hydrolysis of Na_2CO_3, the acid product, CO_2, is constantly removed from the sphere of the reaction.

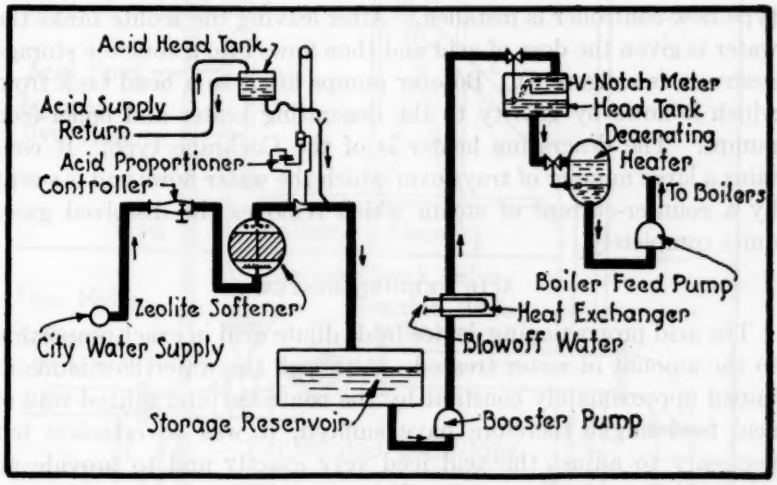


FIG. 6. DIAGRAM OF THE WATER CYCLE

DESCRIPTION OF THE TREATING SYSTEM AT THE BEACON STREET PLANT

The zeolite tanks are 10 feet in diameter and 25 feet long, set with their axes horizontal. They are constructed on the upward flow principle. The true relative merits of the up-flow and down-flow systems were found to be greatly obscured by patent difficulties and commercial considerations, but there seemed to be no fundamental objection to the up-flow system and operating experience has borne out this conclusion. The zeolite is of the green sand type, having a rated exchange value of 3375 grains per cubic foot. The zeolite bed is 41 inches thick and the rate of flow at normal load is

$4\frac{1}{4}$ gallons per minute per square foot of bed area. The total output per tank is 445,000 gallons between regenerations at the rate of 63,600 gallons per hour normal flow and with a maximum permissible flow of 75,000 gallons per hour. There are two of these tanks in the initial installation and the completed boiler plant will require a total of six tanks. The brine required for regeneration is supplied to the zeolite tanks through a simple piping system from a central overhead tank.

The water flows through the zeolite tanks under city water pressure. In order to insure a constant rate of flow which is essential in an up-flow system, regardless of fluctuations in pressure, a venturi type flow-controller is installed. After leaving the zeolite tanks the water is given the dose of acid and then flows into a concrete storage reservoir (see figure 6). Booster pumps lift it to a head tank from which it flows by gravity to the deaerating heater and boiler-feed pumps. The deaerating heater is of the Cochrane type. It contains a large number of trays over which the water flows and is swept by a counter-current of steam which removes the dissolved gases quite completely.

ACID FEEDING SYSTEM

The acid proportioning device feeds dilute acid in exact proportion to the amount of water treated. Although the water flow is maintained approximately constant by the controller and a fixed rate of acid feed might therefore have sufficed, it was nevertheless felt necessary to adjust the acid feed very exactly and to provide an automatic means of cutting off the feed when the flow of water stops. The proportioning device shown in figure 7 was therefore developed.

The acid is diluted to a two to three per cent solution in a central tank and is pumped through lead lined pipe to a constant level tank at each zeolite softener. To the bottom of each tank is connected a piece of rubber hose with a small orifice at its end, the elevation of which, with respect to the level in the tank, (marked h in figure 7) is controlled by a float resting on a column of mercury. This mercury level is controlled by a venturi nozzle placed in the water pipe leaving the softener. There is no stuffing box required and the float moves with practically no friction. Since the flow of acid through the orifice and the flow of water through the venturi throat are governed by a square root law the device gives almost

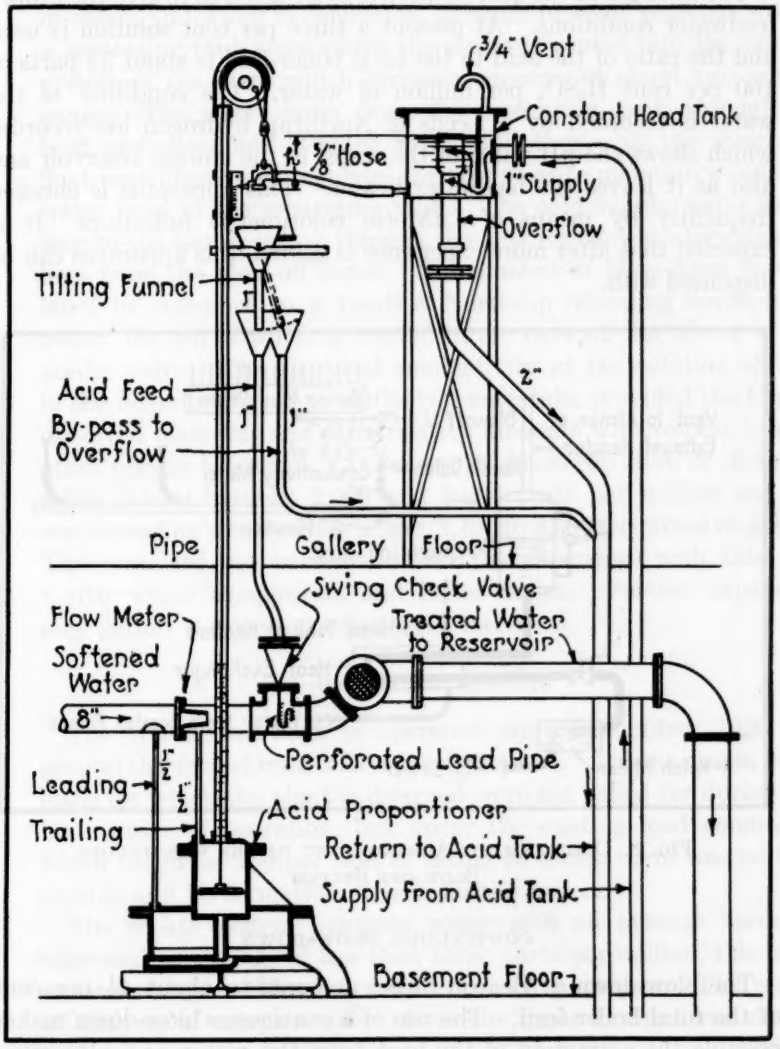


FIG. 7. THE ACID-PROPORTIONING DEVICE WHICH CONTROLS THE FLOW OF DILUTE ACID IN EXACT PROPORTION TO THE WATER FLOW

exact proportioning, the only error being caused by the deflection of the lower leg of the mercury U-tube and this is made negligible by the relatively large diameter of this chamber.

The strength of the acid solution is so adjusted as to give the proper feedwater conditions. At present a three per cent solution is used and the ratio of the acid to the total boiler-feed is about 35 parts of 100 per cent H_2SO_4 per million of water. The condition of the water is recorded by a Leeds & Northrup hydrogen ion recorder which shows the pH value of the water in the storage reservoir and also as it leaves the feedwater heater. This apparatus is checked frequently by means of LaMotte colorimetric indicators. It is expected that after more experience is gained, this apparatus can be dispensed with.

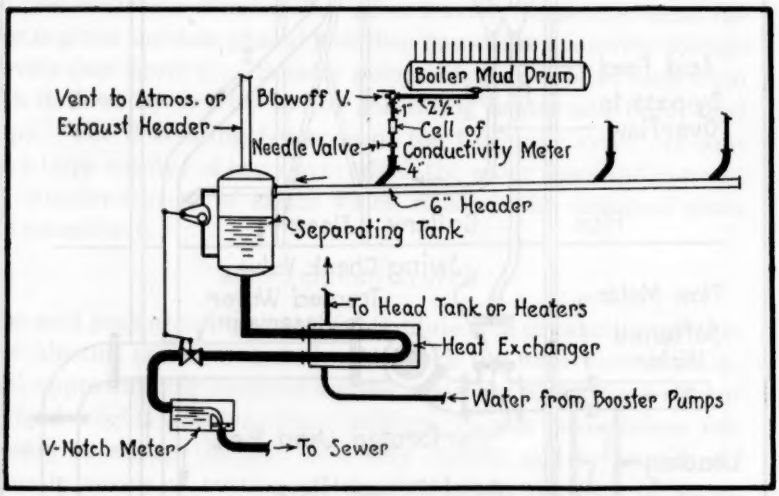


FIG. 8. DIAGRAMMATIC ARRANGEMENT OF THE CONTINUOUS BLOW-OFF SYSTEM

CONTINUOUS BLOW-DOWN

The blow-down at Beacon Street amounts to about $4\frac{1}{2}$ per cent of the total boiler feed. The use of a continuous blow-down makes possible the extraction of the heat from the water and also gives more uniform steaming conditions than would the intermittent blowing off of large quantities of water.

The arrangement of the blow-down system is shown diagrammatically in figure 8. From each of the two mud drums of each boiler there is a one-inch line provided with a needle valve for controlling the flow. As the water passes through the needle valve there is

naturally a considerable amount of steam flashed off and this mixture of steam and water is conducted, through pipes of generous size, to a separating tank from which the steam is vented into the exhaust system of the plant which carries a pressure of about two pounds gauge. The water flows from the separating tank through the heat exchanger and V-notch meter and thence to the sewer. A float-controlled valve regulates the flow so as to maintain a constant water level in the separating tank. The cold supply water on its way to the heater passes through the heat exchanger, absorbing the heat from the blow-off water. The amount of blow-down is regulated by reference to a Leeds & Northrup recording conductivity meter, the cell of which is located in the blow-off line ahead of the needle valve. The electrical conductivity of the solution of salts in the boiler is a measure of the concentration, provided the kind of dissolved materials and their relative amounts with respect to each other remain the same. At present the concentration of dissolved solids is kept between 2,000 and 3,000 parts per million and the corresponding conductivity is from 3,400 to 3,700 reciprocal megohms. This standard has been established by experience with this particular water composition and boiler design. Further experience may permit the concentration to be increased.

OPERATING RESULTS

The system has been in operation since September, 1926. In general the desired results have been obtained. The maximum boiler loads for which the plant is designed were not called for during this first winter of operation, but under the existing load conditions, which called for 250 per cent of rating at times, there was no tube trouble and no formation of scale in the boilers.

The zeolite system produces water with an average hardness, expressed as $CaCO_3$, of less than three parts per million, this being somewhat better than the manufacturer's guarantee. The results of analyses of samples taken at various times during a run on one tank are shown in figure 9.

Table 3 shows the analyses of the water before and after treatment, and table 4 shows the condition of the water at several points in the cycle, using a feed of 35 parts per million of H_2SO_4.

The acid feeding methods have worked out satisfactorily. Very close supervision has been maintained, and of course an acid feed

will always require careful handling, but given such supervision there appears to be no danger of an over-dose of acid. There has been some trouble with the acid pumps and piping system which is no doubt due to lack of experience with this kind of equipment. It appears that the lead lined pipe is not entirely immune from attack by the dilute acid, and the lead pumps have not been entirely satisfactory.

With the normal feed of 35 p.p.m. H_2SO_4 the pH value of the water immediately after the acid feed is low (6.4), but after the water is passed through the deaerator it is increased to 8.5 due to the removal

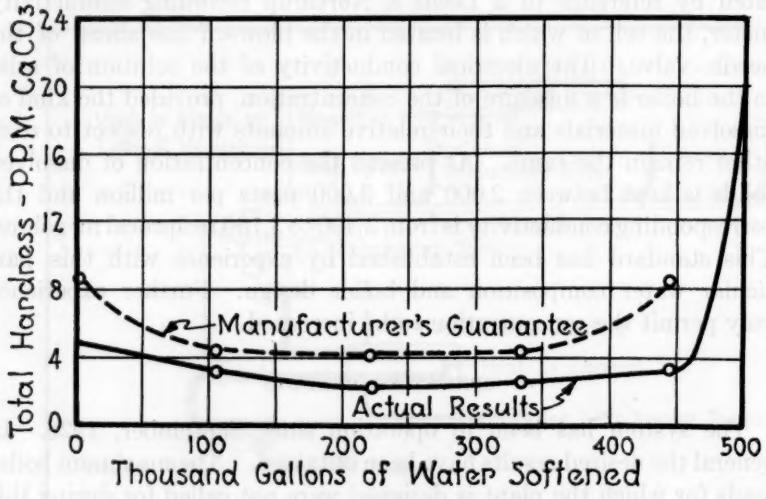


FIG. 9. CONDITION OF THE ZEOLITE-SOFTENED WATER AT VARIOUS INTERVALS DURING A RUN ON ONE OF THE TANKS

of the carbon dioxide, so that the water going to the boilers is well on the alkaline side. Referring to table 4 it will be noted that the acid reacts completely before the water enters the deaerator. The sodium bicarbonate is reduced from 120 to 60.5 p.p.m. by this reaction. In the deaerator the sodium bicarbonate is reduced from 60.5 to 38.0 p.p.m., a reduction of 37.2 per cent, producing an equivalent amount of normal sodium carbonate. This result is somewhat better than those obtained in the laboratory, and although further removal of carbon dioxide could probably be accomplished by steam treatment, it would hardly be justified and is not contemplated.

TABLE 3

Water conditions before and after treatment

All figures in parts per million

	RAW WATER	AFTER ZEOLITE	AFTER ACID FEED AND DEAERATION
Cations:			
Silica	3.0	5.1	5.1
Iron Oxide and Alumina	2.0	0.7	0.7
Calcium	26.4	0.8	0.8
Magnesium	6.4	0.2	0.2
Sodium	3.8	45.0	45.0
Anions:			
Sulphate	20.1	20.1	54.0
Chloride	5.9	5.9	5.9
Bicarbonate	87.0	87.0	27.5
Carbonate	0.0	0.0	9.0
Total dissolved solids	154.6	164.8	148.2
Hardness as $CaCO_3$ (gravimetric)	92.25	2.74	2.74

TABLE 4

*Water conditions at various points in the cycle**

Quantities in parts per million unless otherwise stated.

Acid feed—35 parts of 100 per cent H_2SO_4 per million parts of water treated.

	RAW WATER	AFTER ZEOLITE	AFTER ACID FEED	AFTER DEAERATOR	IN BOILER	STEAM
Temperature, °F	40.0	40.0	40.0	215.0	365.0	365.0
Pressure, pounds, ga	45.0	7.5			155.0	
pH value	7.6	8.6	6.4	8.5		5.4
CO_2 (free)	1.8		18.1	0.0	0.0	25.0
O_2, cc. per liter	6.03	6.03	6.03	0.016		0.044
$NaHCO_3$	0.0	120.0	60.5	38.0		
Na_2CO_3	0.0	0.0	0.0	14.2	174.0	
Na_2SO_4	0.0	30.0	81.0		1500.0	
NaOH	0.0	0.0	0.0	0.0	360.0	
Total alkalinity as Na_2CO_3					650.0	
Na_2SO_4					2.3	
Total alk. as Na_2CO_3						
SO_4					10.0	
CO_3						

* Average of 11 half-hourly readings.

The ratio of the sodium sulphate to the total alkalinity expressed as Na_2CO_3 (the ratio which is important, from the standpoint of caustic embrittlement) is also shown in table 4. The suggested minimum value for this ratio, for the steam pressure in this plant, is 1.0 so that the figure of 2.3 is well on the safe side. The maximum

TABLE 5

Water conditions with phosphoric acid feed[1]

Quantities in parts per million unless otherwise stated.

Acid feed 41 parts of 100 per cent H_2SO_4 plus 24.6 parts of 100 per cent H_3PO_4 per million parts of water treated.

	RAW WATER	AFTER ZEOLITE	AFTER ACID FEED	AFTER DEAERATOR	IN BOILER	STEAM
Temperature, °F	40.0	40.0	40.0	215.0	365.0	365.0
Pressure, pounds ga	45.0	7.5	7.5		155.0	155.0
pH value	7.6	8.4	5.8	8.8		5.4
CO_2 (free)	1.8	1.8	18.1	0.0	0.0	12.0
O_2, cc. per liter	6.03	6.03	6.03	0.016		0.044
$NaHCO_3$	0.0	116.0	24.2	14.6	0.0	
Na_2CO_3	0.0	0.0	0.0	4.1	143.0	
Na_2SO_4	0.0	30.0	88.5	77.5	1600.0	
NaOH	0.0	0.0	0.0	0.0	70.0	
NaH_2PO_4[2]	0.0	0.0	30.0	26.2	0.0	
Na_2HPO_4	0.0	0.0	0.0	0.0	225.0	
Total alkalinity as Na_2CO_3					236.0	
$\frac{Na_2SO_4}{\text{Total alk. as } Na_2CO_3}$					6.8	
$\frac{SO_4}{CO_3}$					13.2	
$\frac{SO_4}{PO_4}$					7.1	

[1] Average of 10 half-hourly readings.

[2] These combinations are calculated in the conventional manner and do not attempt to indicate the exact combinations which are present in the solution.

sulphate-carbonate ratio which is permissible under Hall's theory is 11.1 whereas the ratio actually maintained is 10. An increase of sulphuric acid feed would make the sulphate-carbonate ratio reach the value at which sulphate scale (in minute quantities) might be formed, and a decrease in the acid feed would bring the sodium sulphate-total alkalinity ratio toward the danger line of caustic

embrittlement. There is evidently a margin between these two somewhat conflicting requirements in which it is possible to stay.

RESULTS WITH PHOSPHORIC ACID

As a pure experiment, to determine the possibilities of further decreasing the CO_2 content of the steam, some phosphoric acid was used, for a short period, in addition to the sulphuric acid. The results are shown in table 5. With a feed of 41 p.p.m. of H_2SO_4 plus 24.6 p.p.m. of H_3PO_4, the carbon dioxide in the steam was reduced to 12 p.p.m. The pH value of the water after the acid treatment was 5.8 and that of the condensed steam was 5.4 Although the sulphate-carbonate ratio is above the limit suggested by Hall, the presence of PO_4 would prevent the formation of sulphate scale. The PO_4 content is 150 p.p.m., whereas a concentration of somewhat more than 4 p.p.m. should be sufficient.

These results indicate that it is entirely possible to control the carbon dioxide content of the steam by varying the acid feed and that the use of phosphoric acid for this purpose appears quite feasible, although experience with it has been very limited.

CONCLUSIONS

The zeolite water softening system operates satisfactorily and the acid feed, with careful supervision, appears to be quite practicable and reasonably safe.

The present addition of sulphuric acid sufficient to neutralize about 50 per cent of the $NaHCO_3$ in the zeolite treated water gives a pH value of 6.4 to the water entering the deaerator and a pH value of 8.5 to the water leaving the deaerator and entering the boiler.

The water leaving the deaerator has lost all of the CO_2 set free by the acid and the amount of $NaHCO_3$ which was 60.5 p.p.m. after the acid treatment has dropped to 38.5 p.p.m.

The continuous blow-down through a heat exchanger is satisfactory and the system of ionic control is effective.

The ratio of sodium sulphate to total alkalinity is believed to be amply safe with the amount of H_2SO_4 added.

Inspection of the boiler after eight months of operation has revealed clean tubes and no serious corrosion. There have been no tube burn-outs.

It has been demonstrated that the use of additional acid in the

form of phosphoric acid gives less carbon dioxide in the steam and less caustic alkalinity in the boiler. The necessity of thus reducing the carbon dioxide is not certain and will be justified only if the steam shows itself later to be corrosive with the smaller amount of acid feed. If scale ultimately appears in the tubes when only sulphuric acid is used, it is believed that the addition of a small amount of phosphoric acid will eliminate it.

DISCUSSION

J. R. BAYLIS: I was very much interested in this paper. It shows what might be done with water by chemical treatment. You can take the water and do almost anything you wish with it, but the thing that impressed me most was that any water having over 10 or 15 parts per million CO_2 needs some other treatment preliminary to zeolite treatment. The CO_2 can be very easily removed to 15 or 20 parts per million by perhaps a lime treatment, resulting in much less sodium. We might accomplish approximately the same thing, and get rid of any possibility of corrosive action of the high sulphates or chlorides in the water, before it is blown off.

R. E. HALL: I have been very much impressed by Mr. White's reference to the lesser acidity developed by phosphoric acid, because it opens up a large possibility in the acid treatment of waters, giving also the phosphate radical in the boiler water for the prevention of scale. One other point in the paper that is of especial interest is the figures on oxygen, low in boiler water and low in steam; figures that are within the error of experimental determination, but showing that the oxygen at this low figure is not retained by any action on the boiler metal even though the temperature there is high. One further point I wish to speak of is his certainty that with the phosphate radical in the water, no scale will develop. During the past summer an article appeared in which the use of phosphate, following in that case, I believe, a lime soda softener, was mentioned as giving a hard scale on the boiler. That had been totally outside of any experience that had come to me, and I have been rather waiting for some definite and exact data from totally outside sources that would meet this point. Professor White, in his work here, has given us the best exemplification of what phosphate can do in preventing scale, that we can have.

R. E. GREENFIELD: We have a system of lime soda treatment, followed by zeolite, with no acid neutralization. Mr. Baylis brought out the desirability of removing all of the calcium and magnesium possible with lime, thereby reducing the sodium salts in the boiler feed. I think that is a point very well worth taking into consideration. We have a water that would run very much like the water under discussion, but we get it from zeolite softeners, with only a matter of 50 or 60 parts per million of sodium salts, where Professor White is getting 155. That is the difference in the lime treatment, and that will cut down his acid feed, if he still wants to use that treatment. We have enough acid sulphate in our water to give the ratio of about 1 to 3. We have felt so far that we need not use acid feed on that account. We may use a little acid in order to protect the zeolite from the high alkalinity we now have, but at present it is not necessary because of the carbonate-sulphate ratio. We have had very good success with our system, although there is a little scale in our boilers, but we have been running three or four months, and the scale is not building up. We are not fortunate enough to have continuous blow-off.

O. W. KERRY: I would like to enquire as to the cost of the zeolite treatment, together with the acid treatment, and the approximate cost of the treating plant. What consideration has been given to just the use of soda ash in neutralizing the sulphate carried in the Detroit city water. We think the Detroit city water is a rather simple water to treat, and that scale can be prevented in boilers by the use of about one-half pound soda ash per thousand gallons, at a cost, at Detroit where they make a lot of soda ash, of around $\frac{1}{2}$ to $\frac{3}{4}$ of a cent per thousand gallons. There will be about a pound of sludge formed in the boiler per thousand gallons, but this sludge will be soft and may be readily blown out or washed out. I also notice in this pamphlet that with their continuous blow-down they keep the concentration at from 2000 to 3000 parts per million. That, I believe, represents a loss of about 4 per cent of the total water evaporated. With the use of soda ash, which, from our experience, will keep down scale formation when used at the rate of $\frac{1}{2}$ pound per thousand gallons, the blow-off should be at the rate of about 2 per cent in order to keep the foaming salts below the concentration at which the boilers would foam. Off hand it appears as though this water could be satisfactorily handled with the soda ash treatment

properly supervised, at a very economical cost. I would, like to inquire also as to the boiler pressure carried on the boilers and at what concentration the alkali salts can be carried in the boilers without foaming? That is, the highest concentration of alkali salts with which it is practical for the boilers to operate.

A. R. MOBERG: What is the effect of alkalinity on the zeolite itself. The statement has been made a number of times that the high or excess alkalinities with the lime and soda treatment would be injurious to the zeolite. I have never seen any definite work done on it and I am wondering whether anybody else had done any work to determine whether it is the high alkalinity that is injurious to the zeolite or the chemical action of the lime itself that has a tendency to clog and coat the zeolite? I think that would have a large bearing on the use of lime and soda pre-treatment of zeolite.

A. S. BEHRMAN: Mr. Kerry has raised one or two questions and Mr. Moberg has raised one or two more. Answering the last ones first, it is possible to use the lime-soda treatment before zeolite without intermediate neutralization, provided the treatment is properly carried out. Dr. Greenfield is having that experience now, I believe, and we have several plants under our observation which are operating with the proper lime-soda pre-treatment and which have been in operation long enough to establish the fact pretty thoroughly that there is not going to be any deleterious effect on the zeolite. To answer Mr. Moberg's second question, the principal difficulty which has been experienced, when the lime-soda treatment has not been carried out properly, has been from the active deposition and not from the effect of the alkali itself. We know that any strong excess of sodium carbonate or hydroxide will affect any zeolite deleteriously, but it is not necessary to have either of those conditions present.

Referring just for a moment to Mr. Kerry's suggestion that this matter in question could have been satisfactorily handled by soda ash alone, I am afraid that I echo the sentiments of a great number who disagree very radically with Mr. Kerry on that assumption. If the optimum results are to be attained, and that I take it was the object in Prof. White's work, not only scales should not be formed, but in general the most satisfactory boiler conditions should be obtained. The least one can expect from either a zeolite or a lime-soda softener, properly operated, is to produce no scales. If a zeolite or

lime-soda softener produces scales, the proper place for that equipment is in the lake or any other convenient dumping ground. It is no miracle of any water softening equipment to say that the boilers are free from scale. It is a reflection either on the equipment or on the operators if there is any scale. The objection to the soda-ash treatment alone for the given water in question, as for many waters, is the old story of sludge formed in the boiler. Without regulation of that situation, conditions arose which led some of the older railroads who have tried this treatment to abandon it in favor of complete external treatment when the water demand justified it. The soda ash treatment alone undoubtedly does a lot of good. It does not do nearly as much good in general as a complete treatment, as has been experienced with a number of the railroads here in the west and mid-west. Just one other point I want to raise, which Mr. Baylis has already raised, that is, with a water of this type, which is almost a straight carbonate water to start with, was the zeolite softener the proper device to use? As Mr. Baylis pointed out, the lime-soda treatment with a water of this type would have eliminated at the start, some of the considerations which had to be dealt with in the very efficient manner that Professor White and his colleagues have worked out.

J. H. WALKER: A question was asked about the cost of the treatment. I have no figures but I can assure you that the cost per gallon is high. This matter is discussed in the paper, in which it is pointed out that, if a treatment could be secured which would give a scale-free water, the cost of the treatment was not an important consideration, because, if we can operate a boiler plant at 400 per cent of rated capacity, instead of 200 per cent of rated capacity, the saving in investment cost is very great. We have tried for two or three years a treatment consisting of a straight sodium carbonate treatment, following the lines suggested by Dr. Hall. In this plant we are unable to operate without scale. We have burned out some tubes at 225 per cent of boiler rating, whereas the new plant is designed for 300 per cent or higher. I would suggest that Dr. Hall be asked to speak again on this point, because he is familiar with our conditions at the other plants. The question was asked as to the operating pressure. It is 150 pounds gauge. Another question was asked about the permissible concentration which can be carried without foaming. To identify a foaming condition in a boiler

is a rather ticklish proposition. We had arrived at a concentration of salts which in other plants we had found to be the limiting condition. We have made no experiments in this plant as to whether we could carry a high concentration. It is quite possible we may be able to do so. In connection with the necessity for the acid treatment, we had had no cases of caustic embrittlement. We simply desired to profit by the experience which other people had reported. We had used the sodium carbonate treatment, and with that treatment had kept the suggested ratios of sulphate to carbonate so that we did not expect any caustic embrittlement. An examination of the boilers with this straight sodium carbonate treatment has never revealed any caustic embrittlement, but we are trying to guard against it. As boiler operators, we approached this matter of acid feed with a good deal of respect. We installed several mechanical safe-guards to prevent an overdose of acid, and we have very careful and continual supervision. After eight months of experience we do not really believe that our first fears were justified. The system seems to be reasonably safe, but of course constant supervision will always be required. I would like to propound a question, the answer to which I do not know. Zeolite treatment cuts down the calcium to 1 or 2 parts per million; on the other hand, with several millions pounds of water going into the boiler per day, if all the calcium that does go into the boiler were precipitated as calcium sulphate scale, it would be quite sufficient to cause tube burn-outs, because a very thin scale is all that is necessary for that. Now, does the zeolite treatment in itself produce the freedom from scale? Or is it rather because the relations of the various salts in the boiler are such that scale is not formed, in accordance with Dr. Hall's work?

R. E. HALL: I think I will answer Mr. Walker's last question first, as to the calcium. I cannot answer it on the basis of whether a zeolite treated water will not form scale, but with a reasonable blow-down, there is usually enough alkalinity or carbonate in the water, so that with the very low calcium present in the water, the concentrations will not rise high enough to lay down any of the sulphate scale. That is our viewpoint on that question. As to the question of the burn-out of the tubes which Mr. Walker has brought up, he is so exceedingly thorough in this matter of scale, that sections of tube give hardly enough scale to get a sample of a few grains for analysis. As I look at a tube of that kind, it was my contention that there was

not enough scale there to cause the burn-out, but Mr. Walker insists that if distilled water were in the boiler the tubes would not burn out, and his observation on that undoubtedly is correct. It brings us to the question of foaming in water. It has been our experience in the past year to run across in the lower row of tubes in the B. & W. boiler, scale that ran as high as 20% of sodium sulphate, and with sodium sulphate at 150 pounds pressure operation, soluble to the extent of 100,000 or 200,000 parts per million, it seems impossible that that scale can form unless that tube is practically filled with steam, that is, practically complete evaporation of such water as gets through it. It leads to the thought that these tubes must be filled with bubbles and that those bubbles are relatively small and of slow motion, preventing the heat exchange through the change of state of the water, and therefore allow almost complete evaporation of the surfaces of the bubbles that come in contact with the tube. A water contaminated even with low salt concentration in it, produces bad boiler conditions, and we think that the answer lies in that, rather than in anything else in these cases in which, with an exceedingly small amount of scale, burn-outs occur.

R. O. FRIEND: Answering the question raised regarding the cost of operation of the zeolite water softener installed at the Beacon Street Heating Plant of the Detroit Edison Company, the cost per 1000 gallons of water softened is 0.85 of a cent. This cost is based on the cost of salt delivered at the Beacon Street Heating Plant at $7.00 a ton.

A NEW JERSEY WATER CASE

By Louis L. Tribus[1]

Outside of a few of the larger cities, community water supply, in the generally accepted and understood sense, is covered by a period of not much over fifty years.

The village pump, the rain water fire cistern, the volunteer fire department with its hand power engine, private cisterns and occasional dug and driven wells, served needs of domestic supply and fire protection. Separated houses rarely over two stories, without sanitary conveniences, cared for the populations, and the wells served the family cooking, weekly bath (perhaps), the weekly washing, rinsing the milk buckets and occasional house and window cleaning, outside door steps and porches which always had attention. Streets alternated between dust and mud, and lawns, occasionally cut with a scythe, became green or brown as nature might dictate.

Intensive living had not brought its demands and luxuries, their greater responsibilities and doubtful larger happiness.

The Civil War of 1860–65 was succeeded by many revolutions in living and business and a growth entirely unanticipated—poverty and prosperity, panic and participation in world business. Present conditions are but a repetition on a much broader scale.

New Jersey, as one of the earliest settled states and rather intensively developed in the northern half, has presented many water problems for solution; practical, legal and legislative, in the matters of gathering, distributing and use for transportation, power, manufacturing, municipal and household life.

There has been much published as to the State's supplies for the future and much on record as to rates and diversion, so this paper will pass those topics.

There are five areas, each with its own peculiar conditions: The northeast, with its almost complete residential covering and interdependence of interests; the northwest, fairly mountainous, with

[1] Of Tribus and Massa, Consulting Engineers, New York, N. Y.

scattered towns, but no serious water deficiency at present; the northern coast settlements and their back districts, as yet fairly well supplied from underground sources; the southern coast cities and the southwestern, with Camden as the centre, both groups on the ragged edge of trouble.

This paper will be confined, however, to certain features of the first district, particularly the belt with Elizabeth at the east and Plainfield on the west. That belt takes in some 27 other communities with a population (combined) of some 200,000 or more; in fact, it is very largely one continuing city, spreading north and south of the Central R. R. of New Jersey.

In or about the year 1869 a state charter was granted to the Plainfield Water Supply Company to enable it to provide and sell potable water to the inhabitants of certain prescribed portions of Union, Somerset and Middlesex Counties—Plainfield being then the only fairly well settled part. In later years various county boundary changes were made but of no special import to this review. The Company made no practical use of its franchise until 1889, when it drove some 20 tube wells into the open gravels near Netherwood Station of the C. R. R. of New Jersey, some 2 miles from the centre of Plainfield and began erection of a steam pumping station and the laying of distribution pipes.

Financial troubles stopped the work, but new interests came to the rescue and a good plant was completed. (For description see Paper No. 700, Vol. 31, 1894. Trans. Am. Soc. Civ. Engrs.) Rates were promulgated at an average of terms charged at the same time in a number of the larger neighboring cities.

At about the same time, friendly interests organized the Union Water Company, which proceeded to lay mains in Union County outside of the charter district of the Plainfield Water Supply Company, and to supply such area with water purchased in bulk from the latter's plant at Netherwood. Later the two corporations united forces under the title "Plainfield-Union Water Company," but the source of supply continued as before, except that additional wells were driven and operated by air lift instead of direct suction, and a covered reservoir was substituted for standpipe service. The legality of this union will be referred to later in this paper.

The Elizabethtown Water Company had Elizabeth as its main centre of operations, although a couple of other smaller corporations, Piscataway and Raritan Township Companies, joined in its supply

and service. Several well systems together with the Elizabeth River furnished the water, the latter source being filtered.

The Middlesex Water Company developed a driven well plant at South Plainfield and a surface supply on Robinson Branch of Rahway River.

In 1920 (the last year of full statistics available) about 31,000,000 gallons were being pumped daily by the combined group of companies, whose interests were so fully in common.

Several million gallons per day more were self-served by manufacturing companies who drilled wells for themselves, not always however with much success. The near-surface gravels of the glacial moraine yield a good flow of water and the underlying red shales some more, but the clays so abundant throughout the tributary water sheds do not yield much of any worth going after. Lakes and streams of northern New Jersey, properly conserved and distributed where needed, will give an abundant supply for all community requirements, but full coöperation only, will secure that happy result.

Just prior to the World War, the water companies concerned in this paper, united in a plan to secure an abundant addition by taking water from the junction of the Raritan and Millstone Rivers, which was to be filtered (frequently being very muddy) and delivered in bulk to the different community distribution systems. They bought lands and prepared plans, but the War ended all possible financing. The succeeding great increase in construction costs, without authority to raise sales rates in proportion, prevented any subsequent practical steps for relief.

Meanwhile, summer shortage in supply caught all consumers, forcing curtailment of use and even hardship and community losses, for new industries were loath to settle where water might well be scarce. Many conferences were held between company representatives and locality committees and the type-setters reaped a harvest, but no final relief transpired.

There were three main proposals, viz.:

a. The companies would sell each distribution system to the locality served and with the proceeds, develop the Raritan-Millstone project and thereafter sell filtered water in bulk, for local resale to the citizenry, or,

b. Sell their plants *in toto* leaving the communities to organize one or more water districts and undertake self service, or,

c. Secure authority for such increase in rates as would make it possible to undertake large bonding for new construction.

A fourth scheme was broached, but was scarcely feasible,—viz., that the communities should finance the supply development, under company auspices and subsequent operation.

Much time was lost in these many-sided schemes and the serious drought of 1921 brought acuteness to the situation. For years, Elizabeth had been restive and desired to go alone (as it is now taking steps to do). Plainfield cared little for its neighbors and had for years felt aggrieved that water derived within its area had been furnished to other places, to its own detriment; in fact, it actually has drilled a couple of test wells as a start towards its own system. Naturally with the two larger places either against or luke warm in the consolidated plan, it could only fail. Westfield also started upon a well drilling course.

In 1913 the City of Plainfield went so far as to attack the validity of the organic union of the Plainfield Water Supply and Union Water Companies, hoping, if it could be dissolved, to proceed then to condemn the Netherwood plant and the Plainfield distribution system for its sole city use. The court did not agree and the appeal has never been prosecuted, consequently condemnation was not available.

A very good lawyer has given opinion that in his judgment the union was illegal, but in view of public needs for the water in the larger district, not apparently now available from other sources, he doubted whether any court would risk saying so.

It is an inescapable fact that these various communities have really a united interest, only to be served to advantage by a large private corporation or a well handled public water district commission. Each of the three larger companies applied to the Public Utilities Commission for higher rates, and with considerable justice in their pleas of greatly increased operating costs and larger value of plants in service. Some increase was accorded, but the companies have claimed it was still insufficient to enable new financing for betterments. The Commission took the ground that, when in receipt of generous earnings, the companies had distributed them to stockholders and had put in extended distribution systems to secure more business, but without provision for increased supply and better service to existing patrons. They were therefore not entitled to full relief until they changed that condition.

The Plainfield-Union Water Company has recently appealed to the Federal Court as against rate-rulings of the Commission.

In 1925 the City of Plainfield, still with hopes for more water,

appealed to the State Attorney General for legal relief. The State responded in an action in the Circuit Court in form rarely availed of for such a purpose, viz., "Quo Warranto" proceedings against the Plainfield-Union Water Company, requiring it to show cause why its original charter should not be forfeited; charging wilful violation of duty in not supplying water in abundance for all needs of the population within the original charter area of the Plainfield Water Supply Company. In the latter part of the year the case was tried with an unusual array of counsel, engineers, accountants, city officials, bankers and other lay witnesses, taking about two weeks time of court and jury. The case was based upon points heretofore noted in this paper, with evidence presented that on certain days, various properties and institutions in Plainfield had been deprived either wholly or in part of needed water; that manufacturing plants of great value to the city had had to drive wells of their own because the water company could not supply the demand; that the company's efforts had been to increase the number of consumers, instead of meeting the requirements of those already connected with its mains; and that outside of the abortive Raritan-Millstone project, no steps had been taken to further develop local sources. It was shown that success would have been likely had more wells been drilled and electrically operated as units; at some distance from the Netherwood plant, yet still within the Plainfield area. Further background was provided and used for what it was worth, by both plaintiff and defendant, that very short rainfalls had ruled in 1921 and 1923, not made up by the greater precipitation in 1922, entailing great shortage of supply throughout the whole district. The Plaintiff argued that the company should and could have taken steps looking to emergency relief, without entailing any prohibitive capital outlay.

The defendent contested very vigorously that no wilful neglect had existed or been shown; that it had done all that it was financially able to do under all the conditions; that no more water could be secured locally or at least in worth while quantities, and that, without large increase in rates, no further financing could be accomplished; that, granted excellent earnings in past years, no excessive distributions had ever been made; that such surplus as had been reinvested in pipe lines was fully justified by anticipated future business and that under present conditions stockholders would not contribute moneys for betterments nor could they be compelled to do so.

The case was really rather too technical for a jury. Still it gave

very close attention to the evidence, heard excellent closing arguments and a fair charge by the court. The deliberations were lengthy, but finally the verdict saved to the Company its charter.

As yet no appeal has been taken, so the status quo continues, viz.;

Regular increase in demand for water, without increase of supply in sight, until Elizabeth at least shall have carried out its program of self supply; after which the other communities may get relief, if not dried up from thirst in the meantime.

NOTES

Quo-Warranto-proceedings have been usually taken to prevent official usurpation of power.

A judgment rendered binds all parties because actions are brought by "the people."

Statutes permit such actions in many states but bar them in others.

Kansas—1883—Quo-Warranto will not lie where other legal remedies are adequate.

Alabama—1894—Capital City Water Company vs. State of Alabama. 105 Ala. 406-18 South 62-29 L. R. A. 743. "The fact that a city has, under an ordinance, contract with a water company chartered by the State, the right, on breach of the contract, to rescind the same, does not defeat the right which the State has, on an abuse by the corporation of its franchises, to annul its charter."

A forfeiture of corporate franchise can be enforced only by a direct proceeding by Quo-Warranto.

Georgia—1823—State vs. City of Savannah—R.M. Charlt 250.

Illinois—1844—Williams vs. Bank of Illinois—6 Ill. (1 Gilman) 667.

Illinois—1893—Citizens Horse Ry. Co. vs. City of Belleville—47 Ill. App. 388.

Indiana—1862—Little vs. Danville and W. L. Plank Rd. Co.—18 Ind. 86.

Pennsylvania—1841—Irvine vs. Lumberman's Bank—2 Watts and D. 190.

Virginia—1881—Pixley vs. Roanoke Gas Co.—75 Va. 320.

Pennsylvania—1905—Act. of June 14—1836 (P. L. 621) authorizing the maintenance of Quo-Warranto proceedings against a water company for supplying impure water, is not repealed or modified by Act of Apr. 29, 1874. 34 P. L. 93 providing a method of relief on complaint by an individual citizen.

Commonwealth vs. Potter County Water Company 61 A 1099 212 Pa. 403. The Company had, at low stage of a better supply, mixed impure pond water for use at fires and had an agreement with the borough for so doing, but in the proceeding nevertheless lost its charter.

DISCUSSION

C. C. VERMEULE:[2] Mr. Tribus has set forth in an acceptable manner conditions out of which some of the litigation concerning the Plain-

[2] Consulting Engineer, New York, N. Y.

field-Union Water Company has developed. In view of his connection with the case it is necessary for the writer to make it clear that he has no authority to speak for any of the water companies, and is simply presenting his personal views as a citizen of New Jersey fully in touch with the subject.

The paper shows that the legal remedies at hand available to the several communities are adequate. The Quo Warranto to which he refers, and which was intended to deprive the Company of its charter, can in no way be considered an adequate remedy. It is by no means constructive, since it does not determine who shall ultimately own and operate the property, or provide any remedy whatever for present conditions. On the other hand it was destructive and introduced confusion.

The constructive remedies are those provided by law. Either the communities should take over by purchase or condemnation the water works, or they should be willing to allow to the water companies such rates as will enable them to finance future developments. Such developments they have had in hand for a long time and have expended a very considerable sum of money on some, but they have been unable to go further. Any practical method of financing requires that the revenue to provide for such financing shall not simply be hoped for but shall be in sight. So long as the companies are charged with the duty of providing for the needs of the community, it would seem as if it is their duty to adopt all possible means through litigation or otherwise to provide such revenue.

The situation is that the three companies are supplying a large number of municipalities through sources used in common. In general, according to returns of 1924, the total consumption of water amounted to 26,947,000 gallons daily. Of this 18,058,000 gallons came from driven wells, 6,458,000 gallons from surface water supplied by the companies and 2,431,000 gallons was purchased from outside sources. The district contains in large part a residential population, suburban in character, amounting in the aggregate to about 90,000 persons. The remaining 150,000 population, of which 135,000 is supplied by the Elizabethtown Water Company alone, is largely industrial in character, and the large industries within this district would naturally prefer surface water, softer in character than the well water. On the other hand, the residential portion of the district emphatically declares it is in favor of the well water. Even if the 18,000,000 gallons daily now taken from wells shall be materially

reduced and only the more desirable water used, it will be ample for the supply of this portion of the community for many years to come. Notwithstanding much that has been written on this subject, it is the writer's experience that residential communities are much in favor of well water even though it may be somewhat harder, for it has had marked compensating advantages for their use.

This being the state of affairs, we will turn for a moment to the surface supplies available. Many years ago the water companies obtained the right to take 20,000,000 gallons daily from the Raritan River, this water to be filtered. Raritan River water has been used for many years at Somerville and Raritan after filtration through mechanical filters and has been found very acceptable. Should the companies be permitted to carry this plan into effect, introducing this water into the industrial parts of the district and re-arranging their supplies so that the well waters could be used in the residential portions, immediate relief would be had. The larger part of the supply main necessary for this purpose has already been laid and the pumping station and plant could be quickly constructed.

However, if this plan is not acceptable, the whole district would be relieved should the City of Elizabeth alone take over the distributing system and introduce this supply.

There can be no question that the general plan of supplying this group of communities from a single source through private water companies is the most economical of all plans proposed.

The alternative plan above mentioned is next in rank. While there has been considerable agitation for public ownership, the economy of the present method is apparently appreciated by a large part of the community, consisting of persons best qualified to pass judgment upon it. Furthermore, whenever a move for public ownership has approached the point where the municipalities must immediately face the expenditure of money necessary to carry it into effect there has been hesitation to such an extent that one is left to infer that possibly a much larger part of the community than is apparent really prefers the present method of supply.

There have been various plans urged for introduction of a supply through the State Commission. The difficulty of all of the plans thus proposed is that they call for an unduly large capital outlay in the immediate future, whereas the plan which has been offered by the company provides for immediate necessities at a much smaller cost and is capable of expansion as needed.

There have been certain other difficulties in the way of this plan of a comprehensive supply, and these are inherent in the form of government. This form of government is one which has been preferred by the people of New Jersey and exists at their instance. I cannot state the situation as to this any better than it was stated by Governor Moore in a communication to the Legislature last June, which I here quote.

> Even the State Commissions thus far created have no power to construct water works or to purchase property except at the instance of two or more municipalities, and with funds provided by the same. No attempt to compel municipal governments to coöperate with or submit to assessment by such State Commissions, has been attempted. The home rule spirit has prevailed in all our legislation.
>
> Our State Commissions and their legal and technical staff have naturally felt that their work could go forward more in accordance with their ideas, and faster, if less power rested with the municipalities. Broadly only two methods of accomplishing this have been proposed. The first is creation of an extra municipal authority over a group of contiguous municipalities with power to tax; and secondly direct financing by the State, with the intent, however, to ultimately assess the cost upon the municipalities. The second plan is naturally more acceptable to such municipalities as have thus far failed to provide themselves with an adequate supply of water. Nevertheless it is not evident that the demand comes from them for present action of this kind.

The writer has never regarded the water situation in New Jersey as in any sense difficult from an engineering point of view. Such difficulties as there may be are inherent in the form of government preferred by the people, except as they may be psychological.

QUALITY OF WATER AND INDUSTRIAL DEVELOPMENT[1]

By W. D. Collins[2]

Manufacturing in the United States had its early development in the northeastern part of the country. The movement of the center of population toward the west has been accompanied by a similar movement of industrial development. Although the quality of the natural waters was not a large factor in determining the location of the first manufacturing establishments in this country, it happened that nearly all these plants were able to obtain abundant supplies of clear, soft water.

In 1849 the industrial activity in the States of Ohio, Indiana, Illinois and Michigan, as measured by the value added to raw materials by the process of manufacture, was only 11.1 per cent of the total for the United States. New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and New York together had 47.7 per cent of the total. In the first group of states the water supplies range from moderately to very hard; in the second group nearly all the waters used by industrial plants are decidedly soft. In 1919 the industrial activity in the group of states with hard water was 55 times as great as in 1849 and amounted to 25.5 per cent of the total for the United States. In the states having soft water the activity was only 13 times as great as in 1849 and only 27.8 per cent of the total for the United States. The apparent movement of industrial activity toward the hard-water regions has been brought about more by the development of new industries and plants than by removal of plants from one place to another.

Certain industries have had their greatest growth during the last fifty or sixty years in the places where they were first established. The iron and steel industry, for example, has grown in Pennsylvania

[1] Published by permission of the Director, United States Geological Survey. Presented before the Chicago Convention, June 7, 1927. Based on data in United States Geological Water-Supply Papers 496 and 559, which are now out of print, but are available for consultation in many libraries.

[2] Chemist in Charge, Quality of Water Division, United States Geological Survey, Washington, D. C.

and Ohio so steadily that even though large plants have been established in other states, these two states had 66 per cent of the total business for the United States in 1919. Quality of water is an almost negligible factor in the location of iron and steel mills. The manufacturing of wool and silk goods, on the other hand, has been confined largely to a few states that have generally excellent water supplies. Cotton manufactures were formerly confined to New England. The recent development of the industry in the South is taking place where soft water is available.

The manufacture of food products has developed generally throughout the United States with more relation to population than to any other factor. The location of plants in this industry has been affected only secondarily by the quality of water available.

Every manufacturing establishment uses some power. If the use is small, it is often cheapest to buy electric power and avoid trouble about water supply for a power plant. If much power is required, and especially if steam is to be used in a manufacturing process, as in the manufacture of water gas, the quality of water available is of great importance. Years ago the general conception of a water analysis was a set of figures which in some way indicated whether or not the water was safe to drink. At most these analyses may have given figures for the total hardness as an indication of the industrial value of the waters. About twenty-five years ago the United States Geological Survey began systematic studies of the chemical character of natural waters with reference to their industrial use. The most comprehensive studies on river waters were made about twenty years ago, and the analyses made then are still the most useful information available as to the chemical character of some public water supplies. The recently formed Committee 19 of this Association is now aggressively attacking the problem of proper water supplies for boiler feed and will direct more attention to the industrial utility of waters from public supplies.

Accurate knowledge of the chemical character of the water furnished by any public supply system is necessary for the most effective operation of the plants that use the water and is also necessary to persons or companies who are considering places for the location of a new plant. The operators of the waterworks can get this information for everyone to use at much less total cost than is involved in attempts by a number of different agencies to obtain it. If the

composition of the water varies from week to week the individual cannot learn all he should know about it from a single analysis.

Practically all public water supplies are now safe to drink. There is vast room for improvement of water supplies with reference to industrial use, through better knowledge of the composition of the water, better treatment to make it suitable for industrial use, and better control of the treatment to insure uniformity of quality.

PUBLIC RELATIONS[1]

By Daniel T. Pierce[2]

It will help clarify the subject of this paper if we begin with a premise nobody will probably contradict, namely, that the relations between a utility company and its consumers and customers, between a manufacturer and his "trade," between shippers and travelers and transportation agencies, are truly satisfactory only when there is general confidence that the service rendered is all that can be reasonably expected, that the price charged for it gives a reasonable but not exorbitant profit, and that the management is continually alert to effect improvements in the service.

The purpose of public relations work is to establish such confidence. The confidence must be deserved before public relations work can be successful. Those who have engaged long in such activities know they cannot possibly succeed unless they are based on truth, frankness and good performance. Such specialists will refuse to be connected with anything that lacks such a foundation. Unfortunately, however, there is a great deal of publicity and propaganda being carried on which is so often misunderstood as being public relations work that it will be helpful to trace the development of the latter.

Some three hundred years ago, if a person wished to mould public thought, he wrote or caused to be written a pamphlet setting forth his views. Many of these pamphlets are highly prized by book collectors now and thousands of dollars are spent at book auctions for tracts that were sold for a penny when published. What may be called newspapers were then just beginning to appear, but they were without influence until press censorship was abolished in England in 1698, and then they became party organs. The same is generally true of the early newspapers in this country. During this long period the pamphlet was the chief method of advocating reforms and new ideas.

This method of delivering a message to the public is very poor

[1] Presented at the Chicago Convention, June 8, 1927.

[2] Public Relations Counsel, 120 Broadway, New York, N. Y.

unless coupled with means for assuring that the message actually reaches those for whom it is intended. It was used so long because no substitute was to be had, and the pamphlets were mainly about political affairs or religious questions, the two topics in which men able to read were most interested in those days. A much larger proportion of those able to read were eager to buy such tracts a century or more ago than now, because today the same information is furnished to them in other ways without cost.

When newspapers actually became what we would recognize today as newspapers, between 75 and 100 years ago, and persons began to turn to them for something beside political arguments and religious discussions, their usefulness as carriers of messages about all sorts of things was quickly recognized. Persons burning with zeal for this, that or the other cause tried to get newspaper publishers to print contributions on these topics in which individuals were so much interested. They were only successful, however, as a rule, when they could pay the newspaper proprietor for the privilege of appearing in print.

Now, there was nothing venal about this for two very good reasons. The income of newspapers in those days was very small and most of the articles sent to their proprietors were of very limited interest. The proprietor had to spend his meagre income for what would interest the largest number of readers or be paid for departing from this self-evident rule. This condition did not change much until receipts from advertising increased materially.

With the enlarged income from advertising came the press agent. He distributed advertisements to the publishers of newspapers and at the same time demanded write-ups from them. As his position became more firmly established he demanded more write-ups and developed into a pest we still have with us.

That was not the worst he did, however, for his success in getting crude write-ups printed led him to develop whatever talent he had for authorship, and he produced many quite interesting stories about the persons who employed him or about the goods they had to sell. For a time the hardworking reporters and city editors were glad to get these interesting articles, but they gradually learned that the truth rarely lay in them. When the newspapers realized how very little their readers cared for such interesting but unreliable stories, the press agent lost standing in newspaper circles. There are many of them today, but they have to work very hard and use much more intelligence to get anything printed now than fifteen years ago.

The better men among press agents were glad to give up the spreading of mendacious though interesting stories about actors, politicians, social aspirants and the like as soon as something better offered an outlet for their talents. This opportunity was afforded by publicity work. Its history is interesting. A good many years ago protests against railroads began to increase rapidly. At first railroad men made no reply to them generally. When a reporter succeeded in reaching such an official he was told that there was nothing in such protests so far as that official's line was concerned. Then legislatures began to investigate and afterward to act. Congressmen began to see that real interest was felt in railroad management and policies by influential sections of the public, so they became busy. There were real abuses to be corrected, we all know now, but in those days politics added a mass of fictitious abuses to the real ones, thus producing many indictments against railroad management that still influence public thought to some extent

When the railroads came to a realization of what threatened them, they turned to publicity for help. Some of the indictments against them were easily answered by facts and statistics. Others required explanations of the logical reasons for practices in rate making, such as an explanation of why it was equitable and fair to charge more per hundred pounds for transporting sewing machines than coal over the same distance. And there were other indictments that were so justified that for a time the railway attitude was to keep quiet about them and give lawyers time for study and thought, for the old-school railway managers were very loth to become wholly "good" and proposed to hang on to some practices they had adopted just so long as they could. This was an ideal time for publicity, for giving out nothing but facts about some things, for saying nothing about other things where the facts, if known, might be damaging, and for pointing out errors in facts and logic made in statements by persons attacking the railroads. The issues were too serious to justify giving out untrue information; this is the practical difference between press agent work, which has little regard for the truth, and publicity work, which is based on the literal truth of everything said.

Some of the leaders of railroad affairs soon went a step further, when they decided that the public would never be satisfied and legislators would never let up attacking the roads unless the whole truth were told. They realized it would be years before the public believed them, but they knew the railroads would be running long after

the managers of that day were dead and could be operated by their successors more satisfactorily to everybody if they could regain the confidence of the public. It was then that the public relations counsel proved the value of his services. He was largely influential in persuading railroad owners to realize that they had just as clear a responsibility to the public which granted them franchises to build and operate their lines as to their stockholders who owned the lines and to the bondholders who loaned them money. And he knew where, and how, and when to tell the public everything it had any justification for asking about railroads. That he did and is still doing, and you can see the result in the general confidence in our railroad managements today.

While the steam railroads were passing through their long period of tribulation, the state public utility commissions had been giving attention also to electric railways with the result that they have had a very hard time. There had been many consolidations of small companies into large ones, on the correct theory that a large system can be operated to give better service at a lower cost than many little ones can. But in the consolidation it was necessary to take over many small and often obsolete plants and rolling stock that was poor and inadequate. Large sums of money were needed to provide new equipment, and this money could be obtained only by bond issues as a rule. But electric railway bonds were hard to sell because the utility commissions were reluctant to authorize rate increases to pay the interest on these bonds. Neither the commissions nor the public could appreciate that for the increased fare longer rides in better cars run more frequently than before would be possible. Labor difficulties became frequent; some of the strikes were very serious. Public relations work under such conditions was complicated, multifarious and difficult, but it was making headway slowly until the motor bus arrived on the scene. It introduced so many complications in the local transportation situation that the reorganization of the whole business was necessary. It is going on now, public confidence in the desire of many street railway companies to give good service at reasonable rates is returning, but electric railway companies still face many serious problems.

When we turn to electric lighting companies we see a more pleasant picture. The companies have always been owned to a considerable extent by persons living in the communities they served. They were largely business men and bankers sensitive to local public

opinion; speaking generally, they wished good public relations and they wished enthusiastic employees. They proved this long ago by advocating customer ownership and employee ownership of stock. Their readiness to adopt every new improvement that would keep down the cost of producing current is unnecessary to dwell on. Their desire to make every contact of the public with their employees and with their offices a pleasant one is evident everywhere.

In spite of this record of achievement in public relations work, some of them are going through now one of those episodes which could have been avoided had they appreciated that it is just as important to extend the basic principles of such work into the field of finance as to apply them at home to their relations with their customers. You will recall that some years ago there was a considerable discussion by engineers and by the non-technical public about super-power schemes for tying together steam and hydro-electric stations so as to utilize to the best advantage all the power resources of large districts. Its advantage is that what would be overloads on some stations can be carried by underloaded plants elsewhere in a district.

This superpower feature of electric supply has been carefully studied by the men administering the affairs of many electric companies. It will involve large sums because the transmission lines connecting the power stations cost, roughly, about as much as the stations. Accordingly there was developed the holding company to get together the companies which should be assembled into the superpower system for a district and to provide the funds for the transmission lines and all other items of expense which should not be charged to any one local company but were properly chargeable to the superpower system as a whole. This was a matter of financial administration and understood by financiers concerned with utilities; there has been no secrecy about it. But there has been a good deal of secrecy about the grouping of some local companies into one or another superpower system. Rival interests have been trying to acquire a considerable number of local companies for their respective superpower aggregations. Until the purchases are made every effort is naturally made to keep the negotiations under cover; that is ordinary business prudence and established business custom.

Yet because no general attempt was made to tell the public what is involved in carrying to realization these superpower projects which have a general endorsement by the public, the holding company, the only agency that can apparently be used to finance and administer

such desirable projects, is now being held up by some well-known men as a potential danger. The situation is really amusing, because the men who are organizing these holding companies are as strong believers and practicers of public relations work as we have in the country, and the charges of secret skullduggery brought against them have surprised them greatly.

We have now taken a glimpse at what the railroads, the electric railways and the electric light and power utilities have accomplished by public relations work, and it is time to consider your own problems as water works men. According to your Association's "Manual" there are about 3000 privately owned and 7000 municipal water works in the country. Municipal works, being more or less under political control, will naturally utilize publicity methods of improving their position with the public, for it is rare that politics permits complete frankness.

Men interested in water companies do not need to be reminded that some thirty years ago disastrous financial experiences shook public confidence in such companies seriously. Then came a long period of vociferous demand for public ownership, coupled in many cases with protracted difficulties while public utility commissions were learning enough of the details of water supply to be reasonable in fixing water rates. It was a hard task to earn enough money to pay operating expenses and interest on bonds and the stockholders had a lean time. In the last few years conditions have improved greatly. Courts have cleared away many disputed questions which utility commissions could not settle finally. Water company securities are now readily absorbed and we are seeing many companies taken over by holding companies, a step that will be beneficial to the consumers served if these holding companies are wisely administered, as they presumably will be.

Under these new conditions it is desirable for water companies to begin public relations work, especially where the rates are now too low. It is distinctly short-sighted for companies and ultimately disastrous for consumers to let the idea persist without contradiction that a company need not be paid enough to earn a reasonable profit. When the consumers are awakened to the truth, as they must be eventually, they will have a legitimate grievance against the company that has withheld the facts. There are some persons so constituted that it is very hard for them to be fair, but American men and women, in the mass, are honest, fair and shrewd, and will act justly when satisfied

they are being treated equitably and efficiently. Consequently a considerable part of public relations work must be done by appeal to masses.

This brings us to some of the principles on which any sound and successful public relations effort must be based. Nearly all corporation officials go astray because they insist upon treating discussions with masses of people on the basis of logic, statistics and what they are pleased to term "the facts." We all know, however, that one may have all the statistics and facts on his side, and yet not be able to convince anybody. People in the mass are not moved by statistics. They are moved by actions and attitudes, plus facts which appeal to their imaginations and create confidence and belief.

This is not to say that the facts can be ignored. Facts are absolutely essential and this is a good place to say that no publicity campaign can achieve success that is not founded on honesty and a good cause. Very often it is found that the organization contemplating a public relations campaign looks upon it as an umbrella or screen under and behind which it can do as it pleases. Publicity obviously is a two-edged sword. Don't take it up unless the cause is just and capable of honest defense.

Another don't. Don't expect to hire a public relations counsel or even a publicity man, put him in a corner, leave him out of your councils and expect him to accomplish anything. If this kind of effort is worth taking seriously it is worth all or a large part of the time of a very high-class man who is in close touch with everything that is going on currently, everything that is planned for the future, every major problem of the company he is working for. Tell him everything and let him decide how the company and its acts should be interpreted to the public.

It is very important, also, that communications to the public should be based on an act rather than merely a profession or an editorial deliverance or argument. For example, it is all very well for a railroad to say that it is human and considerate. But if a railroad, as one of them did not long ago, slowed up all its trains passing a house where an obscure individual was very ill, in order that he might not be disturbed, that is a fact from which anyone can be allowed to draw his own conclusion, and those conclusions will be far more positive than could be set up by any amount of assertion.

As to methods, if one wishes to broadcast an idea, there is nothing better than the advertising pages of local newspapers. Nothing, in

fact, anywhere near as effective. There are occasions, of course, when a matter cannot be covered in one advertisement, or, perhaps, not in the most effective way as in series of advertisements. That is where the pamphlet comes in. And pamphlets are made much more effective if they are distributed with a letter to the key men of the community with the request that the company's statement be given consideration and the facts it sets forth weighed before any opinion is formed. Very often it is necessary to get small groups of individual critics together and talk to them. They are flattered that this trouble is taken to convince them. Furthermore, talks of this kind give an opportunity for give and take and the answering of mental reservations which will otherwise not be brought out.

There is another kind of public relations effort that is represented by so simple a matter as keeping equipment, employees and plant neat and attractive. This has a tremendous effect in persuading the public that the company is anxious to do things properly. Shabby-looking equipment and personnel make just the same effect on the customer of a utility that a gloomy, dusty store and frowsy clerks make on you when you enter such a place.

Contact with newspaper men is something about which it is difficult to generalize; however, there are one or two rules that may be mentioned. The first is to trust them. Don't try to jam a lot of publicity down their throats. Make them welcome. Tell them about things in advance. Educate them before a rate increase is to be asked. Satisfy them before things get into the atmosphere of contention and agitation when it is practically impossible to secure a judicial consideration of any matter. That is where most of the trouble comes in with utilities, as every public relations man knows. He is rarely sent for until the house is on fire and then he is expected to perform some overnight miracle which is impossible.

Another most important factor in the establishment of good public relations consists, not in the declaration of benevolent intentions or worthy purposes, but in activities that show a real interest and concern over the consumers' welfare. Tell what things are actually done to improve service; what investigations are made; what exchange of information to assist this work goes on among similar companies. Water works men, I assume, are studying all the time to improve their service, which means safe-guarding the health and welfare of millions of people. Personally, I have never seen anything printed on the subject; a statement which indicates I do not read your

"Journal." How many persons in any of the cities from which you come will ever read it? Every new piece of equipment or extension of importance should be talked about in papers that are read; the good relations with newspaper men, previously mentioned, will bring this about.

You will realize, I am sure, how difficult it is even to outline a subject such as this, because anyone who for twenty-odd years has been dealing with public relations problems knows that no two of them are alike except as to some of the general principles that have been mentioned, and in one other respect, namely, that effort of this kind must be continuous. Don't fool yourselves by thinking that the publication of a few advertisements and the distribution of a few pamphlets have reached everybody and convinced everybody. You are looking for every little item that concerns you and you are likely to assume that because you have seen it everybody else has seen it.

They haven't. You may be sure of that. The only really consistent piece of public relations work that has ever been done is that of the Bell telephone organization. In season and out, fair weather and foul, good times and bad, they have talked about their service, explained its ramifications, why they need so much capital, why they need the rates they charge, and what is the result? Today they can probably sell more common stock at a higher price than any other industry in the country. No more impressive proof can be given of the effectiveness of good publicity continously applied.

John M. Goodell

Born August 3, 1867
Died June 21, 1927

Mr. Goodell became a member of the American Water Works Association on April 27, 1894, and was the editor of its JOURNAL from 1917–1921. For some years he was a member of its Publication Committee and the secretary of its Committee on Standard Form of Contract. He had much to do with the establishment in 1920 of the Standardization Council and from its beginnings he was one of its most wise and constant advisors.

In the passing of Mr. Goodell the American Water Works Association loses a member who was among the best informed as to its history and growth and who persistently and effectively worked in a quiet way for a long term of years to bring about its development in size, strength and usefulness. In his death the Association loses a helpful and powerful influence which he exerted so modestly and cautiously that comparatively few members knew about the time and strength which he devoted so advantageously to the advancement of the Association.

Mr. Goodell was born in Worcester, Massachusetts, and was graduated from the Worcester Polytechnic Institute in 1888 with the degree of Bachelor of Science in Civil Engineering. During the next two years he studied engineering at the Polytechnic Institute at Zurich, Switzerland. He then joined the editorial staff of *Engineering News* for two years and next was an associate editor for two years of *Engineering Record* after which for three years he was assistant secretary of the American Society of Civil Engineers.

From 1897 to 1902 he was associate editor of *Engineering Record* following which he spent a year on paper mill construction as a member of the staff of Joseph H. Wallace at Sault Ste. Marie. In 1891 he published a translation from the German of Baumeister's

book on *The Cleaning and Sewerage of Cities,* and in 1899 another book on *Water-Works for Small Cities and Towns.* From 1903 until 1912 Mr. Goodell was editor-in-chief of *Engineering Record.*

Later Mr. Goodell was engaged on editing work for Metcalf & Eddy on their three volumes on *American Sewerage Practice,* and he also was occupied with the reorganization of the American Concrete Institute as well as with the development of the American Highway Association.

Beginning in 1917 Mr. Goodell resided for two or three years in Washington where he was connected with publicity work for several activities, most of which were related to the war. He was employment manager first for the production division and later for the entire Emergency Fleet Corporation. During the latter part of the war he was acting chairman of the National Highway Council and later was consulting engineer to the Bureau of Public Roads, chiefly on its plans for organization and publicity.

After the war Mr. Goodell returned to New York to reside and became actively engaged in editing work chiefly as related to publicity and advertising and to the preparation of concise summaries of technical reports for the use of business establishments. He also did important work of a statistical nature for several large companies. One of his principal clients was the Babcock and Wilcox Company.

In spite of the very active part which Mr. Goodell played at Washington during the war he consented in 1917 to become editor of the JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION and continued his efficient work, particularly in getting out papers of short and moderate size of practical benefit to the water works industry. He resigned as editor in 1921 to assist Metcalf & Eddy in condensing their three volumes on *American Sewerage Practice* into the so-called 500-page "Textbook" for use in colleges. After 1921 the efforts of Mr. Goodell to advance the standing of the Association continued unabatedly, particularly with respect to the activities of the Publication Committee and plans for the preparation and publishing of the *Manual of Water Works Practice,* the quality of which in many particulars is a splendid testimonial to the ripe experience and foresightedness of its former editor.

Mr. Goodell was not in robust health during the later years of his life, but continued with characteristic energy and persistence to carry on during long hours, contrary to the advice of his physician.

He remained at his desk until June 18, when he complained of feeling badly and was taken to the French Hospital in New York. Shortly afterward he suffered a stroke, had another on June 19 and a third on June 21 which caused his death.

He is survived by his widow, Mrs. Letha L. Goodell; a son, John Boyden Goodell, who resides in New York; a married daughter who resides in Oakland, California, Mrs. Dorothy Goodell Remsen; and a younger daughter, a student at Vassar College, Miss Barbara Letha Goodell.

GEORGE W. FULLER.

Charles Randolph Wood

Died June 8, 1927

The death of Charles R. Wood, which occurred so suddenly during the convention of the American Water Works Association, was not only a great shock and a tragedy to all those in attendance at the annual meeting in Chicago, but also spread great sorrow among the members at large as it became known through the public press and our technical publications.

He had seemed especially interested in this convention and, for many months preceding it had taken every opportunity to predict its great success and encourage a large attendance.

At the convention itself for the few days we were privileged to have him with us, he was particularly eager to assist, not only in the way of entertainment in which, as always, he was so kindly and so generous, but also in the many other activities of the Association. Probably the last signature he wrote was affixed late on Wednesday morning, June 8, to a report of the Convention Committee of which he was a member, and his last official act for the Association came just before noon on that same Wednesday, when at a meeting of the Nominating Committee, he made a motion that the vote on the selected nominees be made unanimous.

On the adjournment of this meeting he walked from the committee room down the adjoining hallway and spent some moments talking with a number of his friends; but having doubtless some premonition of the coming attack he went, when the opportunity came, into one of the small conference rooms to rest for a moment and then started, unfortunately alone, to go to his own room. Before he was able, however, to reach the entrance of the elevator his strength gave out and he was assisted by hotel attendants through a strange coincidence, into the same room in which, but a short time before, his Convention Committee had been meeting.

The house physicians were immediately called and did the little that could be done for this attack which was pronounced acute dilation of the heart. Before he lost consciousness, the doctors asked him if he had any friends in the hotel, and his reply was characteristic, "Yes, I think I have lots of friends, but don't bother them." Not long after, the end came.

While Charles R. Wood's firm held an Associate Membership in this organization, he himself was an Active Member and ever took a great deal of pride in the American Water Works Association. He was always intensely interested in its success—not passively or intermittently. Our Executive Committee and the Secretary's office continually sought and welcomed his counsel and suggestions.

In this Association no single member had more friends or a wider acquaintance. He had never held an office in our Association, but his position in our affections was very high, and is secure. The place made vacant by his death will be very difficult to fill.

BEEKMAN C. LITTLE.

RESOLUTION OF AMERICAN WATER WORKS ASSOCIATION ON DEATH OF CHARLES RANDOLPH WOOD

WHEREAS, the late Charles R. Wood departed this life the 8th day of June, 1927, at the Hotel Sherman, in the city of Chicago, and during the Forty-seventh Annual Convention of the American Water Works Association, in which he was taking an active interest, and

WHEREAS, the deceased has for many years been an active and stimulating influence in the councils of our Association, having given of his best to the advancement of its interests, and

WHEREAS, we, members of this Association will miss his counsel and advice in our circle, and his friendship and good fellowship in our social relations;

Therefore Be It Resolved, that we, the members of the American Water Works Association, in session at our annual meeting in the Hotel Sherman, Chicago, Illinois, June 9th, 1927, regret his untimely demise and hereby register this expression of our loss, and it is

Ordered that this *Resolution* be spread upon the minutes of this meeting, and that a copy of these *Resolutions* be embossed and forwarded to our deceased member's family.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Tensile Properties of Soldered Joints Under Prolonged Stress. J. R. FREEMAN, Jr., and G. W. QUICK. Metal Ind. (New York), **24:** 7–10, 1926. From Chem. Abst., **20:** 1212, April 20, 1926. Tensile tests of lead, tin, and 50–50 solder were made by applying definite stresses to wires 6 inches long and 0.1 in. in diameter, and measuring the elongation with time up to 28 days. Lead was found to support stress of 415 pounds per square inch without failure. Tin showed constantly increasing elongation under stresses greater than 230 pounds per square inch, and solder gave same result under stresses above 70 pounds. Test specimens of soldered joints were lap-joints of galvanized iron and sheet-brass. Apparatus for securing constant temperature and pressure in making specimens described and illustrated. No creep was observed in any soldered-joint specimen at shearing stresses up to 400 pounds per square inch. No specimen jointed with tin failed at this stress. Joints made with solder showed failures at 400, but not at 200 pounds per square inch. The 50–50 solder failed before 60–40 (lead-tin respectively), and galvanized iron joints failed before brass joints.—*R. E. Thompson.*

Prevention of Scale and Rust. DE GRAHL. Gesundh. Ing., **49:** 45–6, 1926. From Chem. Abst., **20:** 1291, April 20, 1926. Precipitation of normal carbonates is prevented by addition of a soluble chloride to the water, sufficient being added to change part of calcium content to calcium chloride. Method recommended for household installations.—*R. E. Thompson.*

The Behaviour of Iron, Bronze, and Brass in Solutions of the Salts and Salt Mixtures Contained in Waste Liquors from the Potash Manufacture at Ordinary Temperature and at Temperatures and Pressures Prevailing in Steam Boilers. O. BAUER, O. VOGEL, and K. ZEPF. Mitt. Materialprüfungsamt Kaiser Wilhelm Inst. Metallforschung, 1925, No. 1, 62 pp. Chem. Abst., **20:** 1211, April 20, 1926. Systematic determination of iron, bronze, and brass corrosion in resting and moving solutions of magnesium chloride and sulfate, sodium chloride and sulfate, calcium chloride, and various mixtures of these, in potash liquors, in river waters, and in distilled water. Tables given including data for salt concentrations used and corrosion results over period of 30 days. Following are conclusions drawn. Bronze and brass are only slightly attacked by the salts and waters. Magnesium salts at ordinary temperature in con-

centration corresponding to 112–9 German degrees of hardness are not dangerous to iron. Magnesium salts in feed water to steam boiler must be regarded as dangerous, increasingly so with concentration. Explanation of this is given in hydrolytic decomposition of magnesium salts at high temperature and pressure, producing effect of acid.—*R. E. Thompson.*

The Action of Dyes Used in Paper Making on the Animal life of Streams. O. HAEMPEL. Z. Nahr. Genussm., **50**: 423–6, 1925; cf. C. A. **6**: 784. From Chem. Abst., **20**: 1291, April 20, 1926. Effect of various dyes on fish and other lower water animals was determined.—*R. E. Thompson.*

Separating Scale-Forming Ingredients from Boiler Feed-Water by Preheating and Sedimentation. O. GUNTHER. U. S. 1,579,444, April 6. From Chem. Abst., **20**: 1679, May 20, 1926. Mechanical features.—*R. E. Thompson.*

Action of "Hot Wall"; a Factor of Fundamental Influence on the Rapid Corrosion of Water Tubes and Related to the Segregation in Hot Metals. C. BENEDICKS. Trans. Am. Inst. Min. Met. Eng., February, 1925 (advance copy), 30 pp. From Chem. Abst., **20**: 1211, April 20, 1926. Although it is known that dissolved air in water has a serious corrosive effect on water tubes, it is not conceded that gradual liberation of air from water or presence of entangled air can account for localized corrosion of, e.g., boiler tubes, and to account for this a condition designated as "hot wall" is introduced. Hot wall is a condition converse to that produced by permitting gas containing vapor to come in contact with cold object on which part of vapor will be condensed if plate is below dew point. Thus if a liquid (water) containing a gas (air) comes in contact with hot plate, a new gaseous phase is produced and bubbles of gas separate on plate. This is supposed to occur in boiler tubes, and the gas bubble being non-conductive causes hot spot on tube, and any chemically corrosive action which may be proceeding more or less slowly will be accelerated by rise in temperature. This view may explain localized corrosion which occurs when different metals are used in construction. Remedy is to remove dissolved air prior to contact with metal tubes. Action of hot wall is special case only of spontaneous concentration differences that may occur in primarily homogeneous solution when subjected to locally different temperatures (Ludwig-Soret action).—*R. E. Thompson.*

Chemical Relation of Salt Dome Waters. H. E. MINOR. Bull. Am. Assoc. Petroleum Geol., **9**: 38–41, 1925. From Chem. Abst., **20**: 1290, April 20, 1926. Chlorine content of ground waters from Texas and Louisiana salt domes has been found useful in identifying source of waters and in correlation of water-bearing sands. Amount of chlorine is lowest in near-surface water and increases downward, reaching saturation near salt of shallow cores; but in domes of deep-seated type rising gradually at rather uniform rate below 2000-foot level.—*R. E. Thompson.*

Determination of Chloride in Water. H. W. VAN URK. Z. anal. Chem., **67**: 281–8, 1925. From Chem. Abst., **20**: 1290, April 20, 1926. Mohr's titration

method is discussed critically on basis of mass-action law and as result of mathematical study certain improvements in technic are suggested. The concentration of chromate should lie between 0.7 and 1.5 millimoles per liter. The pH value of water titrated should be between 7 and 11. If water is alkaline to tropeolin 0 or acid to rosolic acid, it should be neutralized. Most suitable pH is 9, at which point phenolphthalein is barely pink. Magnesium oxide is unsuitable as neutralizing agent but sodium bicarbonate is advantageous. Water saturated with magnesium hydroxide has pH value of about 11.—*R. E. Thompson.*

Comparative Study of the Oxidation Number of Water by the Kubel-Tiemann Test and of Its Chlorination Number. KARL KEISER. Gas u. Wasserfach, **69**: 42–3, 65–9, 1926. From Chem. Abst., **20**: 1290, April 20, 1926. Determination of organic matter in water free from albuminous decomposition products may be made by potassium permanganate oxidation (Kubel method) or by chlorination (Froboese method); but if water is contaminated with sewage, the chlorination method must be used for exact results. Comparisons of the two methods are given for various types of contaminated waters in 15 tables. In certain cases chlorination of raw water increases filterability by influencing colloidal nature of its organic matter.—*R. E. Thompson.*

The Chemical Reaction of the Rusting of Iron. JOH. SCHEIBER. Farbe u. Lack, **31**: 11, 125, 1926. From Chem. Abst., **20**: 1585, May 20, 1926. Review of electrochemical theory of corrosion.—*R. E. Thompson.*

Calcium Chloride Waters from Certain Oil Fields in Ventura County, California. F. S. HUDSON and N. L. TALIAFERRO. Bull. Am. Assoc. Petroleum Geol., **9**: 1071–88, 1925. From Chem. Abst., **20**: 1199, April 20, 1926.—*R. E. Thompson.*

Probable Origin of Thermal Waters of Aix-les-Bains, Savoy, and the Rôle of the Tectonic Accidents in the Thermalization and Mineralization of the Springs. W. KILIAN. Soc. Geol. Belg. Livre jubilaire, 1874–1924, 97–102, 1925. From Chem. Abst., **20**: 1199, April 20, 1926. A geological study.—*R. E. Thompson.*

The Action of Water Containing Ammonia on Pipes and Boiler Plates. M. TILGNER. Chem. Ztg., **50**: 48, 1926. From Chem. Abst., **20**: 1211, April 20, 1926. Water containing 8–15 p.p.m. of ammonia showed strong corrosive action.—*R. E. Thompson.*

Public Swimming Pools. R. MESSER. Virginia Municipal Review, **3**: 9, 341, September, 1926. Solution of public swimming pool problem involves rigid enforcement by local health department of minimum requirements for public health safety. These include a satisfactory source of water supply, a minimum replacement with new or re-purified water, and the provision of ample toilets and showers.—*G. C. Houser.*

Typhoid Fever as a Menace. W. F. KING. Monthly Bulletin, Indiana State Board of Health, **29**: 10, 147, October, 1926. Too many Indiana public water supplies are notoriously bad, with every inducement offered for typhoid. Analyses made by State Health Department in 1925 show that of 1,378 samples from public supplies, 151 were bad. Most of these bad samples were from supplies obtained from streams, ponds and lakes.—*G. C. Houser.*

Actions Speak Louder than Words. E. L. FILBY, Florida Health Notes, **18**: 11, 159, November, 1926. Outlines work performed by sanitary officers of State Board of Health during emergency brought about in Florida by storm of September 18. At Fort Lauderdale, application of chlorine to the water supply direct from a cylinder was resorted to. Chlorine sterilization was employed at Miami and Hollywood, excessive doses being applied in order to clean up the distribution systems.—*G. C. Houser.*

What You Should Know About Your State Department of Health. Connecticut Health Bulletin, **40**: 12, 279, December, 1926. Work of Bureau of Sanitary Engineering consists of sanitary supervision of public water supplies, public sewage treatment plants, shellfish areas and production methods, and ice supplies; inspection of swimming pools, slaughter houses, summer camps and boarding houses, and roadside water supplies; investigations of questions of private water supply, sewage disposal, and nuisances in coöperation with local health officers.—*G. C. Houser.*

Rural Sanitation. H. E. MILLER. Health Bulletin (North Carolina State Board of Health), **42**: 1, 16, January, 1927. As a result of the enforcement of "The State Sanitary Privy Law," passed in 1919, 126 new public water supply systems and 130 new sewerage systems have been installed. The building of new water works was made possible by the fact that additional revenue from increased consumption brought the system to a self-sustaining basis. The typhoid fever death rate has been materially reduced from the rate of 1918.—*G. C. Houser.*

Cross Connections in Connecticut. W. J. SCOTT. Connecticut Health Bulletin, **41**: 1, 3, January, 1927. Regulations adopted by the Public Health Council provide that after December 31, 1926, no cross connections shall exist between potable and non-potable water supplies, except that installations protected by double check valves of approved type, with adequate facilities for testing, which were in existence on December 31, may be temporarily permitted with the approval of the State Department of Health.—*G. C. Houser.*

Typhoid Epidemic at Watseka. T. J. BROPHY. Illinois Health News, **13**: 1, 21, January, 1927. In October, 1926, Watseka, with a population of about 3,000, had a typhoid epidemic, during which 31 cases and 3 deaths were reported. The outbreak came soon after a flood in the Iroquois River, which receives the sewage of Watseka. It is suspected that the city water supply, which is derived from wells, became polluted during the high stage of the river.—*G. C. Houser.*

Webb-Lattin Water Bill Would Fix Responsibility. Health News (N. Y. State Department of Health), **4**: 6, 21, February 7, 1927. Bill before New York legislature would fix responsibility for failure to take necessary steps when a water supply is known to be dangerously polluted. Bill provides that failure to carry out emergency recommendations of commissioner of health shall constitute presumptive evidence of negligence.—*G. C. Houser.*

Conservation of the Waters of the State by the State Department of Health. H. P. CROFT, Public Health News (N. J. Department of Health), **12**: 3–4, 74, February–March, 1927. Policy of the department is that the discharge of sewage into waters of the state shall be so regulated that the inhabitants are not caused injury in health, comfort, or property. In those municipalities that must discharge sewage into waters used as sources of water supply, the department requires that the sewage be subjected to sedimentation, oxidation, and disinfection.—*G. C. Houser.*

Resolution Prohibiting Bathing in Potable Waters of New Jersey. Public Health News (N. J. Department of Health), **12**: 3–4, 100, February–March, 1927. In December, 1926, the Department of Health resolved that no person shall bathe in any stream, lake, or reservoir, the waters of which are the source of a public water supply for domestic use, if, upon examination and investigation, the department determines that bathing pollutes said water for potable purposes.—*G. C. Houser.*

Report of Bureau of Sanitary Engineering, Maryland State Department of Health, 1926. ABEL WOLMAN. 19 pp. Activities of Bureau during 1926 with regard to water supply, sewage disposal, oyster investigations, stream pollution, aerial pollution, and camp sanitation are reviewed. Total value of work represented in plans submitted during year was $3,143,000. The percentage of population using public water supplies has increased from 62 in 1916 to 71.6 in 1926. The percentage using treated supplies increased during this period from 54.9 to 66.3, the percentage using public supplies served with treated waters having increased from 88.4 to 92.7. Studies on stream pollution included conditions in regard to disposal of wastes from pulp and paper mills, garbage reduction plant, canneries, laundries, creameries, pigment manufacturing plant, and steel rolling mills. During period of high fish mortality, investigation showed many of dead and dying fish to be infected with flagellate-like spores. Tables given showing typhoid death rate in Maryland, inclusive and exclusive of Baltimore, and in Baltimore for years 1910–1926 inclusive, the rates being 7.4, 9.7, and 5.2 respectively for 1926. Tabulation of distribution of typhoid deaths in relation to population groups for years 1920–1926 inclusive, shows that major portion of mortality is occurring in populations aggregating less than 2500. Efforts are being made to provide municipal water supplies in populations of less than 1000 now that this has been accomplished to large degree in populations exceeding 1000, and it is hoped that this will improve the typhoid situation. Regulations passed on July 1, 1926, state that "no physical connection shall be permitted between a potable water supply and an industrial, fire, or other auxiliary or emergency

water supply." It was required that all existing cross-connections be removed by October 1, 1926.—*R. E. Thompson.*

Report, Corporation of Madras Water Analysis Laboratory, 1925. S. V. GANAPATI. 46 pp. Brief report of work carried out, replete with tables and graphs of results of analyses and studies undertaken. It has been observed that the organic content of the raw water varies inversely with level of water in lake, being excessive during months of April to September due probably to decay of vegetation when lake level is low. The purifying effect of sedimentation and exposure to sunlight is evident in May, June and July, during which period the number of lactose fermenters is less. As in previous years, none of the slow sand filters yielded consistently good results. Hydrogen sulfide was evident throughout the year. Tap samples examined resembled raw water bacteriologically except during an experimental period of one month during which the supply was chlorinated. The dominant organism in the white filamentous growths in filter chambers, etc., previously reported on (cf. this Journal **17**: 271), was found to be Crenothrix polyspora: Vorticella and another organism of "colonial habit," probably Carchesium or Zoethamnium were also found.—*R. E. Thompson.*

Irregularities in the Test for B. Coli in Water. RUDOLPH E. THOMPSON. Jour. of Bact., **13**: 209–21, March, 1927. Observations and results of experiments on the problem of non-confirming presumptive positive B. coli tests at Toronto, Canada, are given. The failures are of two types, (1) those probably due to presence of aërobic or anaërobic spore-forming lactose-fermenting bacteria or gas-producing symbiotic complexes, and (2) those in which colon group bacteria were originally present and lost in the confirmatory procedure. The latter only are discussed. Typical examples of results obtained when pollution was known to exist are quoted in which the indicated concentration of B. coli would have been 100- to 100,000-fold greater if the losses had not occurred. These failures are believed to be due to the production of an inhibiting H-ion concentration during preliminary enrichment. It is pointed out that while it is generally known that B. coli is inhibited by the acidity formed by its own growth in carbohydrate-containing media, this fact does not seem to have been seriously considered as a factor in the failure of presumptive tests to confirm. Assuming that the failures were due to the production of a lethal pH, three series of comparative tests were made with standard broth and broth containing dipotassium phosphate. Of 300 tubes each of standard broth and standard broth containing the buffer salt, inoculated in parallel, the total numbers positive confirmed were 166 and 232 respectively. In the majority of instances a much larger number of colonies was obtained from the buffered medium than from the standard broth inoculated from the same sample of water. When the same medium is employed for examination of both 10 cc. and 1 cc. quantities of water, as recommended in Standard Methods of Water Analysis, the composition after dilution with the sample varies widely. To eliminate this variation, three strengths of lactose broth are used in Toronto, the composition and amount per tube being so proportioned that when the desired amount of water has been added the composition of the resulting mixture will be the

same in each case. Three quantities of water are employed, namely, 1, 10, and 100 cc., the amounts of media being 9, 15, and 50 cc. respectively and the strength ratio 1:1.5:2.7, taking the strength of standard lactose broth as unity. The final composition in each case is practically the same as when 10 cc. of standard broth is employed with 1 cc. quantities of water according to Standard Methods. In all the above tests 10 cc. quantities of raw Lake Ontario water and the second strength broth were employed. The modified broth contained 2 grams of dipotassium phosphate per liter, corresponding to 1.33 grams per liter of standard strength broth.—*Frank Hannan.*

Water Supply for Army Railways in France. PAUL M. LABACH. Proc. Am. Soc. Civ. Eng., **53**: 4, 540–62, April, 1927. The factors ordinarily taken into consideration in the supply and distribution of boiler water for commercial railway purposes are outlined briefly. This is followed by a discussion of the difficulties encountered in changing the water supply and distribution systems of several light traffic commercial railways into suitable installations for a unified military railway with very dense traffic. An outline of the organization of forces used in the work is given, together with a discussion of recommendations for an organization which would aid in simplifying and expediting similar operations. Water for boiler use is one of the fundamental requirements for railroad operation. The tonnage to be hauled was estimated to be 60 pounds per soldier per day at the base ports. About one-third of this would be unloaded before the advance section was reached. The actual tonnage was only 3 per cent less than the estimate. Two million men were in France in November 1918. Estimates of materials and locations of water stations which would be needed in an advance to the Rhine were made. Efforts also were made to procure all materials well in advance of the necessity for its use. It was one year after the United States entered the war before a department that was to be responsible for all water supplies used in the Transportation Service was organized. The tanks of the American locomotives held 4,900 to 5,300 gal. of water. The rate of consumption was 70 to 120 gal. per mile with a locomotive having its full tonnage rating. A maximum span of 30 miles with an average of 20 to 25 miles between water stations was adopted. The standard distributing equipment consisted of a 50,000-gallon wooden tank with 10-inch threaded pipe couplings from the tank to the crane. The rapid increase in the size of the Army produced such a density of traffic as to bring out forcibly the need of adequate watering stations. Lack of suitable material was the most serious factor in delaying construction.—*John R. Baylis.*

Probability of Flood Flows. F. G. SWITZER. Proc. Am. Soc. Civ. Eng., **53**: 4, 563–69, April, 1927. Frequency curves may be applied to flood data in determining flood flow probabilities. A few curves are given to show how the probability curves are used.—*John R. Baylis.*

The Sanitary Water Board of Pennsylvania. W. L. STEVENSON. Water Works, **66**: 117–19, 1927. The policies and accomplishments in three years of operation of the Board are outlined.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

Taste and Odor Removal in Water at St. Paul, Minn. Ross A. Thuma. Water Works, 66: 124, 1927. The St. Paul water supply is diverted from the Mississippi through a series of lakes and filtered. Copper sulphate treatment to control algal growths in the lakes has been practiced for ten years. Many complaints are received, because of the odors from the algal growths and decomposition of organic matter. Coagulation reduces but does not eliminate the odors. Softening with lime and ferrous sulphate failed to remove the odor. Aëration with 6000 cubic feet of air per million gallons has been found sufficient to reduce the odor to a minimum.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

Safeguarding the Water Supply of New York City. William W. Brush. Water Works, 66: 47–49, 1927. The water delivered by the Catskill aqueduct from the Ashokan reservoir, which is 92 miles from New York City, is chlorinated three times with average doses of 0.25, 0.17, and 0.26 p.p.m. before it reaches the city. The water supply obtained from Croton Lake, about 30 miles from the city, is chlorinated twice with average doses of 0.6 and 0.3 p.p.m. before it reaches lower Manhattan. The third system, the Long Island Supply, is a system of infiltration galleries served by three pumping and chlorinating stations and is used largely to supplement the other supplies. These three supplies produced about 213, 67, and 23 billion gallons respectively in 1925.—*C. C. Ruchhoft.* (*Courtesy Chem. Abst.*)

Leakage Surveys in Chicago. Anon. Water Works, 66: 69–70, 1927. Public Works, 58: 56–58, 1927. A review of the leakage surveys made by the water pipe extension division from 1907 to 1924. The surveys showed that universal metering is the only way the problem of the ever increasing water consumption can be solved. At Hegewisch the per capita consumption dropped from 433 to 75 gallons after meters were installed in 1920.—*C. C. Ruchhoft.*

Water Waste Investigation in Syracuse. E. P. Stewart. Public Works, 58: 73–5, 1927. The city, which has 270 miles of mains, is divided into 3 sections, and each section is divided into districts of various sizes for water waste survey. Gauging points were established at strategic locations. The night rate is determined with a Pitot recorder, after isolating the district. If the consumption is low, work on another district is started, but if high, the district is further subdivided and the distribution of the night rate determined. At Syracuse, if the rates are 20,000 g.p.d., or over, per average city block, they are investigated. Leaks are detected with aquaphones and electric leak locators employing a microphone, which are the most valuable aids for the work. Leaks as great as 125,000 g.p.d. have been found, though most leaks vary from 20,000 to 60,000 g.p.d. Syracuse is nearly 100 per cent metered and has a gravity system, but the money used in water waste survey work is considered well spent.—*C. C. Ruchhoft.*

"Water Dogs" in a City Water Supply. R. A. Polglaze. Public Works, 58: 97–8, 1927. An Alabama city of 40,000 has had trouble with "water dogs," *amblystoma punctatum*, in the water supply. It was found that they were breeding in an uncovered reservoir. The reservoir was cleaned and the water

treated with copper sulphate. A heavy one-eighth inch mesh was placed over the outlet pipes and a 56-inch fence with the bottom 30 inches covered with one-quarter inch mesh wire cloth was built around the reservoir. Since this work was completed there have been no further complaints due to "water dogs."— *C. C. Ruchhoft.*

The New Water Supply of Wellsville, Ohio. R. D. McGILL. Water Works, **66**: 89–96, 1927. Wellsville, which is located on the Ohio River about 40 miles below Pittsburg, has taken its water supply from the Ohio River for many years. Because of the very high pollution of the Ohio at Wellsville this supply was condemned in 1921 and abandoned in 1925. The new supply is taken from an impounding reservoir of 142 m.g. capacity which was constructed by building a dam at the junction of Bailey's Run with Little Yellow Creek. This provides a gravity supply of 2 m.g. per day and will maintain a pressure of 70 pounds in the city mains. The design, construction, and operating features of the system are described.— *C. C. Ruchhoft.*

Alkalimetric Determination of the Hardness of Industrial Waters. C. BELCOT. Chem. Ind., **46**: 3, January 21, 1927. Bull. Soc. chim., 1926 (iv), **39**: 1648–1652. The values obtained for the permanent hardness of a water not containing alkali carbonates or hydrogen carbonates by the method of TREADWELL or of PFEIFER (Z. angew. Chem., 1902, **15**: 9, 198) often disagree with those obtained by difference. The discrepancy is due to the partial solubility of magnesium carbonate. Hence, in a water containing alkaline-earth and alkali hydrogen carbonates, magnesium sulphate and chloride, and sodium carbonate the total carbonate and hydrogen carbonate is determined by titration. The total hardness is then determined, and the permanent hardness determined after boiling the water and neutralising the alkali hydrogen carbonates with hydrochloric acid. (S. K. T.)—*A. M. Buswell.*

Pollution of Streams in Illinois. Illinois State Water Survey, Bulletin **24**: 1927. This report, prepared in coöperation with the State Department of Conservation, contains information on pollution in each drainage basin by sewage and industrial wastes. The data are both summarized according to counties and also presented in the form of spot maps according to drainage areas.— *A. M. Buswell.*

The Disposal of the Sewage of the Sanitary District of Chicago. Illinois State Water Survey, Bulletin **23**: 1927. Alvord, Burdick & Howson. This bulletin is a publication of a report by Alvord, Burdick and Howson, consulting engineers of Chicago, by order of the Secretary of War and submitted to the District Engineer, U. S. Engineer Office, Chicago. It discusses in detail the amount and type of purification required for Chicago sewage, assuming various diversions of water from Lake Michigan, to safeguard the city's water-supply and to preserve fish-life in the Illinois River. As a basis for the conclusions reached, quantities of valuable scientific data have been compiled.—*A. M. Buswell.*

Summary Report on the Water Resources of California, and a Coördinated Plan for their Development. PAUL BAILEY. California Dept. Public Works Bulletin 12, 1927. This report, with its appendices, completes an investigation of the water resources of California started in 1921. It comprises a survey of water supplies and flood flows throughout the state, a determination of their characteristics, an estimate of the present and future needs for water, and the formulation of a comprehensive and coördinated plan for future development that will insure adequate water supplies for all purposes. A coördinated plan for the development of the waters in major geographic divisions of the state provides for the storage of flood waters for conservation purposes, the transportation of surplus waters of the Sacramento drainage basin to the deficient areas in the San Joaquin Valley, an adequate summer flow in the Sacramento River for navigation and salt water control, the resumption of hydraulic mining in the Sierra Nevada Mountains, the control of floods by reservoirs, the expansion of irrigation along the lower Colorado River in south-eastern California, and the diversion of water from that river to the Pacific slope for municipal purposes.—*A. W. Blohm.*

City Water Supplies of Arkansas. HARRISON HALE. University of Arkansas Bulletin, **20**: 18, November, 1926. Because of the importance of public water supplies, the Engineering Experiment Station, University of Arkansas, began in 1924, a state-wide survey of the public water supplies of that state. The bacteriological and mineral analyses of the waters, together with a brief description of supplies of 82 cities and towns in Arkansas are given.—*A. W. Blohm.*

Proceedings of Fourth Annual Short School, Texas Association of Sanitarians. October 27–30, 1926. These proceedings are divided into seven sections as follows: (1) Aims and objectives of the Association; (2) Organization; (3) Public Health Education; (4) Waste Disposal and General Sanitation; (5) Food Protection; (6) Water Supplies; (7) Disease Control Procedure. **Water Supplies: Sources of Public Water Supplies.** V. M. Ehlers. P. 127. In appraising a spring supply, the source of origin cannot always be traced. If it is fed by surface drainage its flow will be more or less intermittent, and the spring flow should therefore be measured over a long period of time, including wet and dry seasons. In considering well supplies it is desirable to determine the nature and extent of the water bearing strata. A safe and acceptable water for drinking and domestic purposes should be palatable, clear and odorless and should not contain any harmful bacteria, excess of mineral salts or poisonous compounds.—**Standard Practice for Sanitary Protection of Sources and Units in a Water System.** E. W. STEEL. P. 129. Care of watersheds and reservoirs is necessary to produce a water requiring a minimum of treatment. Necessary precautions in the sinking of a well and the construction of basins and small reservoirs and distribution systems are briefly outlined. Valves on cross-connections may leak or be tampered with, especially when it is considered that the personnel of factories and water works changes and that newcomers probably will not understand

the possible consequences of the entrance of polluted water into a public supply. For this reason cross connections should be eliminated.—**Water Purification.** LEWIS O. BERNHAGEN. P. 134. The importance of water as a food makes it essential that it be pure and wholesome. An account of a typhoid epidemic in Minneapolis, an extract from Ellms' "Water Purification" and the United States Public Health Service drinking water standard are given.—*A. W. Blohm.*